JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXX OCTOBER, 1915 No. 4

DEVELOPMENT AND RECENT ADVANCES OF THE TECHNO-GRAPHIC ARTS.*

BY

LOUIS EDWARD LEVY,
Photo-Chemist,
Member of the Institute.

AMONG the many new influences which are affecting our daily life in this modern time, when the arts are racing with the sciences in a rivalry for progress, not the least are those which are being exerted through the recent advances of the pictorial arts. Up to within the time of these developments all the various methods of pictorial representation could properly be included under the general designation of the Graphic Arts. A picture or design of any kind, on whatever substance it may be wrought, whether drawn with pencil, pen and ink, or crayon, or painted in oil or water colors, or engraved with cutting tools or etched with acids, is essentially a product of Graphic Art. Such are the delineations of animals and fishes found among the remnants of the cave men of the Stone Age of Europe, incised on bone with tools of chipped flint, perhaps a hundred thousand years ago; the designs indented on pottery by the Swiss lake dwellers

* Presented at the meeting of the Photographic Section held March 25, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

of the Bronze Age, some fifty thousand years ago; the colored pictures remaining on the walls of cave dwellings of the same period, and the similar productions of other primitive peoples in

Engravings on bone, mingled and superposed. Grotto of Lorthet, Hautes-Pyrénées, France. (Éduard Piette, *Revue d' Anthropologie*, 1904.)

various regions of the globe through all the ages down to the present day. The decorative designs and pictorial representations traced in stone on the walls of temples and monuments that remain to us from ancient Egypt and Assyria, the engravings on

stone and other material referred to in various passages of the Bible, the paintings on pottery and on walls that remain from the centuries of classic Greece and Rome, are all of them productions of Graphic Art, and so likewise are the similar remains of the early East Indians and of the pre-Columbian inhabitants of Mexico and Peru. Every such production being complete in itself and affording, moreover, not only a presentation of its subject but also a direct indication of the individuality, the mood of mind and the handicraft of the worker, is naturally to be classed as a product of what may be termed the Manual Graphic Art.

Engraving around piece of reindeer antler among remains in Grotto of Lorthet, Hautes-Pyrénées, France. (Eduard Piette, *Revue d' Anthropologie*, 1904.)

But when we come to consider such productions as are not complete in themselves, but require to be supplemented by the printing art, and by that means may be duplicated indefinitely, we must regard them as belonging in a separate category, which has been designated as the Reproductive Graphic Arts. Such are those of engraving on wood, copper, or steel, in which, however, the manual skill of the worker is still the sole and direct agency in the process of production. An indirect agent comes into play when acid is applied to engrave by etching a design which has been drawn by hand on a metal plate, but the skill of the draughtsman is still

the essential factor in producing the result. Practically similar is the case in lithography where the design has first to be drawn by hand on the stone before the natural repulsion of fatty substances and water can be utilized in printing from it. Thus the arts of wood and copper plate or steel engraving, etching and lithography, appertain in principle to the Manual Graphic Arts. These various arts had reached a practically complete development when, about 1870, their field came to be invaded by the photo-engraving processes and the productions of the hand engravers began to be rivalled by those of the camera. This rivalry of the photographic with the manual graphic arts had its inception as far back as 1813, when an early French lithographer, Joseph Nicéphore Niépce, began working out a process of photo-engraving on lines pointed out by earlier discoveries of the light-sensitive properties of certain resinous gums. After a long series of experiments in this direction he succeeded, by about 1824, in obtaining a light-sensitive medium composed of asphaltum dissolved in a special oil. A film of this solution, flowed on plates of metal and dried, presented a substance which was so changed by the action of light that it became insoluble in the oil. On exposing the sensitized plate to light passing through a transparent paper print the part shielded by the print remained soluble, and when washed away by the solvent the design showed up on the bare metal. The undissolved film of asphaltum protected the plate sufficiently to permit the bare portions being etched, thus producing an intaglio photo-engraving. A specimen of these early productions, an etching on a plate of tin, made in 1825, has been preserved in the Niépce museum at his birthplace, Chalon-sur-Saône, and is doubtless the oldest production of a photographic process extant.

The asphaltum film was not sensitive enough to be practicable for use in the camera, but Niépce appears to have obtained with his crude instrument, the camera obscura of his day, by very prolonged exposures in brilliant sunlight, some pictures, both on glass and on metal plates, some of the latter silver plated. The pictures thus obtained were negatives, the thin asphaltum film being dissolved out in the development more or less as the exposure had affected it, the lights of the picture being thus represented by the dark undissolved portions of the film and the shadows by the white surface of the silver plate. To reverse the effect, Niépce subjected his finished plates to fumes of iodine,

Reproduction of print from intaglio plate, photo-engraved by Niépce, 1824. Earliest photographic result extant. rom the print in National Museum, Washington, D. C. Negative by courtesy of Thos. W. Smillie, Honorary Custod- of Photographic Section.)

which darkened the silver surface by converting it into silver iodide. The asphaltum was then washed off with alcohol, leaving the picture showing black on white. In the course of these experiments Niépce noticed the change produced by light on the iodized silver surface of his plates and tried them in his camera. By prolonged exposure, yet much shorter than was necessary with his asphaltum method, he could obtain a visible picture on the plate, but it was not as satisfactory as the other, nor could he find a way of fixing it. While working to improve his method Niépce was brought in contact with the Parisian scene painter, Louis J. Daguerre, who was also trying to fix the image of the camera obscura and was experimenting to that end with phosphorescent substances. They combined their efforts in a partnership, Niépce contributing his process and Daguerre his improvement of the camera, but each continuing to work at his own home. Niépce kept on improving his process for photo-engraving purposes, while Daguerre sought some way of making it practicable for the camera. Two and a half years after they started in partnership,—that is, in July, 1833,—Niépce died, leaving his son Isidore to take his place. Daguerre kept on, but gradually abandoned the asphaltum film in his efforts to find some way to utilize the much greater light-sensitiveness of the iodized silver surface. At last, in 1837, after another four years' groping, both literally and metaphorically, in the dark, he accidentally discovered the secret that he sought. To get a visible picture on the iodized silver plate quite a long exposure was necessary, while with a shorter exposure nothing at all showed up on the plate. A number of such underexposed plates had been stacked away by Daguerre in a closet of his dark-room, to be later cleaned off for further use. On taking them out he was astonished to find a visible picture on the outermost plate. He at once surmised that something in the closet had brought about this effect. To find the active agent he proceeded to remove the contents of the closet one after another, leaving a plate to be worked upon after each removal. Having taken out everything that he could find and the effect still continuing to be repeated, Daguerre was at his wits' end when he discovered in the closet some globules of mercury that had remained unnoticed. Following this clue, he succeeded in working out the Daguerreotype process, which consists essentially in the application of mercury vapor to develop

the latent picture on the iodized silver plate. The all-important factor in Daguerre's discovery was its revelation of the existence of an unseen photographic image that could be developed chemically.

After vainly trying for two years to get financial support in exploiting the invention, Daguerre and young Niépce concluded to offer it to the government, and to that end applied to the well-known scientist Arago. He at once recognized the importance of the new art and announced the discovery at a session of the Academy of Sciences on January 7, 1839. Through his influence and that of the Academy the French Government was induced to purchase the secret of the process and give it to the world. In July, 1839, a life pension of six thousand francs to Daguerre and of four thousand francs to Isidore Niépce was accorded by the French Government, and on August 19 the full details of the process were made public in a communication by Arago to the Academy.

At this very time another important discovery in the field of photographic chemistry was formally announced through the Royal Society of Scottish Artists by Mongo Ponton and published in the new *Philosophical Journal* of Edinburgh in May, 1839. Ponton had experimented on the lines indicated by the French chemist Vauquellin, who had discovered chromic acid in 1795 and had observed that the red color of chromate of silver became purple on exposure to light. Ponton found that paper impregnated with bichromate of potassium was very sensitive to light. By placing a translucent object on such sensitized paper and exposing it to light he produced a picture of the object in tones of brown, modulated according to the varying amount of light passing through the object, and could fix the picture by simply washing it in water.

At another juncture this discovery would have attracted universal attention, but the dramatic announcement and governmental publication of Daguerre's discovery produced such a furore among the general public, and in the scientific world as well, that not only did Ponton's discovery go unnoticed but the promising results in photo-engraving that had been obtained by Niépce were also entirely overlooked. A striking commentary on this condition is the fact that the Daguerreotype, notwithstanding its early improvement by Herschell, and later by Fizeau,

JOSEPH NICEPHORE NIÉPCE. 1765–1833.

had before 1870 become a thing of the past, while Niépce's method, further developed and improved by his cousin, Niépce de St. Victor, about 1850, came gradually into extensive use and remains so to this day, and the photo-engraving processes based on Ponton's discovery have become universally applied.

Not until over ten years after that discovery was any notable effort made to develop its possibilities and then only in some modifications of Ponton's method of obtaining chromate prints on paper, by Becquerel in 1840 and Robert Hunt in 1843. Then again nothing was done with it for another nine years, but this time a long step forward was made by Fox Talbot, an English physicist, who had early devoted his efforts to researches in this field and had worked out a method of photography on paper sensitized with silver chloride. Talbot's experiments, following the direction of Ponton's work, led to the discovery that gelatine sensitized with bichromate of potash, when exposed to the action of light, became insoluble. Availing himself of this peculiarity, Talbot worked out a process of photo-engraving in intaglio and obtained a patent for it in October, 1854. The process consisted in flowing on the polished surface of a steel plate a solution of bichromated gelatine, letting this dry in the form of a thin film, exposing it to sunlight through a transparent positive, then washing out the unreduced bichromate with water and finally etching the plate through the unaffected portion of the film with chloride of platinum or of iron. Talbot conceived the idea of producing the effect of halftones by breaking them up into minute subdivisions of the engraving. This result he obtained by first exposing his sensitized plate under a screen of fine network, such as a piece of gauze, and then under a transparent positive of his subject, or, as an alternative, placing the screen between the positive and the sensitized plate and exposing them together. Talbot's intaglio etchings pointed the way to the subsequently developed process known as photogravure, and his application of the screen of gauze was the beginning of the halftone process. In his patent specifications he noted that the process could be applied for the production of photo-lithographs and of relief etchings on zinc, and called attention to the fact that even the thin film of gelatine on his steel plates, when immersed in water to wash out the unreduced bichromate, swelled sufficiently in the unexposed portions to produce a considerable effect of relief. Altogether,

with the exception of special uses of the asphaltum process, Talbot's combination of the bichromate sensitizer with a gelatinous substance became the starting-point of all the modern photo-reproductive processes. The number of these, in their various modifications, has become legion, and still more numerous are the names by which they are sought to be identified. Even for the category in general several terms have come into use, such as photo-mechanical, photo-chemical, photo-reproductive arts, etc. The distinguishing feature of all these methods of graphic representation is that the skill of the worker plays only a directive part, the creative work being accomplished by the unconscious forces of nature through the application of scientific technology. It may therefore be permitted, if only for the sake of brevity, to denominate these methods of pictorial representation as the Techno-graphic Arts.

The development of these arts on the basis of chrome gelatine compounds proceeded in three principal directions: as a resist for etching, as a mould for electrotyping, and as a printing surface directly. Each of these possibilities presented numerous different ways of applying the principle involved, and it was not long before some of them began to be practised. Immediately after Talbot's publication Paul Pretsch, of Vienna, obtained an English patent for a process of applying the swelled gelatine film as a mould on which to produce electrotypes. By addition of silver iodide to his gelatine solution the swelled films produced a grain of varying fineness, according to the gradation of light and shade of the negatives or positives used for the exposure, thus furnishing photo-reproductions in halftone both in relief and in intaglio.

In the following year, 1855, Pretsch patented a method of producing by this process intaglio-engraved copper cylinders to be used for printing on textile fabrics, a premonition of the rotary photogravure process of the present day.

During these same years Alphonse Louis Poitevin, in Paris, who had previously worked out a method of turning daguerreotypes into intaglio engravings by galvanic etching, was working in the same direction as Pretsch, and in 1855 obtained a patent for a process similar to his. But his really important contribution to the progress of the Techno-graphic Arts was his method of printing direct from the exposed and developed chrome gelatine film on the principle of the lithographic process.

LOUIS JACQUES DAGUERRE, 1787–1851.
From a photograph copy of daguerreotype by Charles Meade, Paris, 1848. (*Snelling's Photographic and Fine Art Journal*, New York, January, 1855.)

He modified the chrome gelatine solution by adding albumen, gum arabic, and other colloidal substances, and after due exposure and washing out the unreduced bichromate from the film he passed over it a roller carrying a fatty ink which adhered only to those features of the plate that remained dry through having been affected by the light, and was rejected by the moistened ground. From the film thus inked up prints could be taken on paper and, if desired, transferred to lithographic stone and printed from that. So was started at once the practice of photo-lithography and of collotype printing. The former was afterwards, in 1859, simplified and improved by J. W. Osborne, in Melbourne, Australia, through his method of applying the chrome sensitizer to lithographic transfer paper direct, and further developed by numerous other workers of that period. Poitevin's collotype method, that of printing from the gelatine film direct, remained to be perfected by subsequent workers during the decade of the sixties, notably by Jacob Husnik in Prague and Joseph Albert in Munich.

Still another opening was made by Poitevin in the course of his fruitful activity through his application of chrome gelatine films colored with lamp-black or other pigments and dried on paper. By adding other ingredients to the gelatine solution the film became easily soluble in warm water, and was washed away in proportion as it had remained shielded in the exposure. This was the beginning of the pigment or carbon printing process which was afterward improved by John Pouncy in 1858 and practically perfected by J. W. Swan in 1864.

About the same time a new and very important application of the gelatine wash-out principle was made by Walter B. Woodbury through his process of printing with a pigmented glutinous ink. His method was to use the gelatine relief to produce an electrotype from which the glutinous ink, held in the graduated depths of the plate, was transferred to paper in corresponding gradations of quantity, thus producing pictures with a complete gradation of tone. In 1866 he modified the process by replacing the electrotype with a matrix obtained by pressing the dry and hard gelatine relief into sheet lead and transferring the glutinous ink from that. This process, known as the Woodburytype, came into extensive use and held its ground until gradually superseded by the collotype printing method.

In 1872 Woodbury patented a method of applying his process to the production of rolls from which to print in the cylinder or rotary press, thus reversing the method patented by Pretsch in 1855, by utilizing the wash-out instead of the swelled gelatine process for the purpose. Neither method, however, was found practicable.

The method of procuring intaglio photo-engravings in grain effect by etching the plate to modulated depth through the exposed gelatine film, which Talbot had devised at the very beginning of his work in 1854 and had patented as the first of his results, was gradually improved in its details, first by Talbot himself and afterwards, during the sixties, by several of his followers. Among these were a number of French workers, notably Dujardin and Rousselon, who, by applying the wash-out gelatine process devised by Poitevin and modified by Swan and Woodbury, obtained, both by electrotype and etching process, intaglio photo-engravings of a quality which left nothing to be desired and which made the Parisian art publishing house of Goupils famous. The method by etching was afterwards, about 1880, simplified by an Austrian worker, Carl Klic, but, through having been brought to its full development in France, it continues to be known everywhere by its French term, photogravure.

Yet another pioneer worker, Georg Scamoni, chief of the photographic section of the Russian Imperial Printing Office at St. Petersburg, added materially to the progress of the Techno-graphic Arts during this period. He worked out, about 1865, a method of photo-intaglio-reproduction by electrotyping on the metallic deposit which forms the image on the developed collodion plate, after first building this up to a sufficient relief by repeated redevelopment and intensification. His line reproductions by this process were used extensively for official documents and show a remarkable degree of delicacy of line and stipple.

From this time on the field of the Techno-graphic Arts rapidly widened out and the number of workers in it grew apace. I became one of these in Milwaukee in 1869 as an experimenter with swelled gelatine along the lines marked out by Pretsch, at the same time finding occasion to learn the methods and also the troubles of the collotype process. After a long interruption I began again in Baltimore in 1873, and in the following year

MONGO PONTON, 1804-1885.

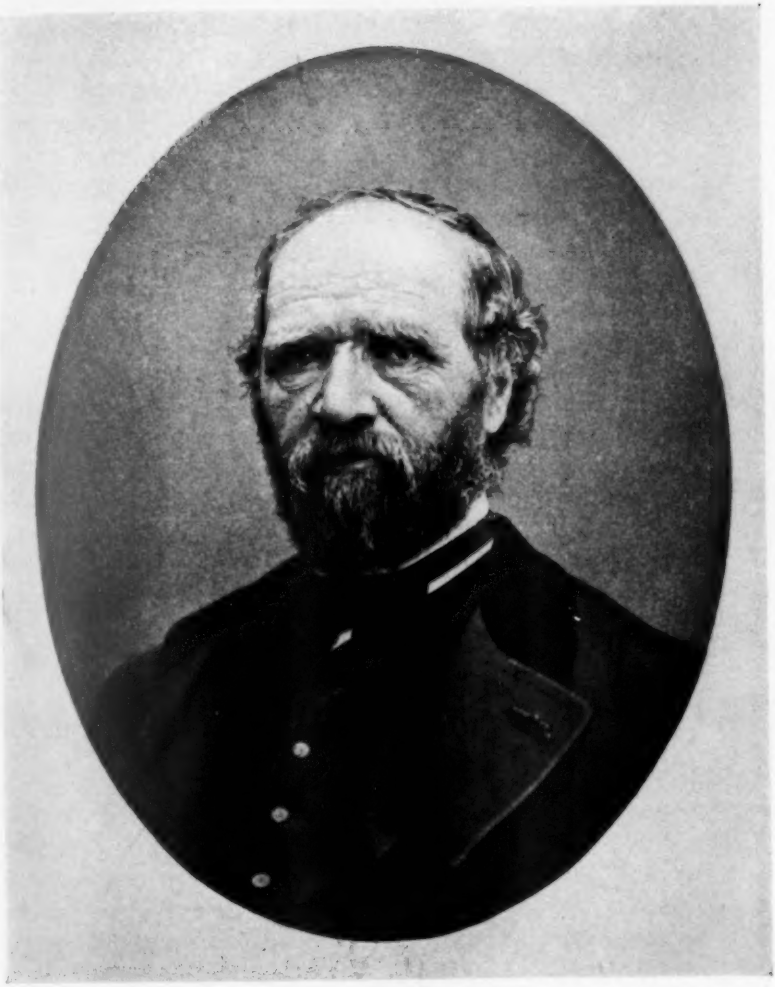
obtained the facilities of David Bachrach's photographic gallery and also his coöperation in the working out of a new photo-electrotype process which, to distinguish it from its predecessors, we called the Levytype. Its essential features consisted in swelling the exposed chrome gelatine film in solution of silver nitrate, making this electrolytic by changing it into a sulphuret and electrotyping the mould thus produced. For this process we obtained a patent which was published in January, 1875.

In May of the same year a photo-electrotype process based on Poitevin's method of washing out the unexposed gelatine film instead of swelling it was patented by William Mumler, of Boston. His method was an adaptation of that of Fontaine, worked out in Paris in 1862, which consisted in washing out the unexposed portion of a thick chrome gelatine film and electrotyping the dried gelatine relief. This method found considerable application both in Europe and this country until superseded by the zinc etching process.

After working the swelled gelatine process commercially for about a year I came gradually to taking wax casts from the gelatine film and electrotype moulds from these, and from this it was but a step to using the wax casts for making plaster moulds in which to produce the relief plates in the form of stereotypes. My next step was taken in 1877 in the form of a removal to Philadelphia. Here, in 1880, I took up the zinc etching process which had long been practised in Europe, notably by Gillot in Paris, and which was then being used for the production of the *United States Patent Office Gazette*. In this process a photo-lithographic print was transferred to the surface of the polished zinc plate, the transfer strengthened with asphaltum powder melted into the ink and the plate then etched with nitric acid, leaving the surface protected by the inked design standing in relief. As the etching proceeded the vertical sides of the standing lines required to be protected against the action of the acid, and this was effected by applying additional ink and powder to the surface of the plate and then heating it to make the ink run down over the sides of the exposed lines. This was repeated usually seven or eight times until the etching had reached a sufficient depth for the requirements of the printing press. My experience with this method soon led me to the expedient of sensitizing the surface of the zinc instead of the paper

and producing the design on the plate directly by exposure instead of indirectly by transfer. I next came to replace the inking-up and melting-down method of protecting the exposed lines of the etching by covering them instead with a shield of resinous powder brushed against the projecting lines and melted into place. This was done four times at right angles across the plate and proved to be sufficiently effective to permit the etching process to be completed in three or four stages instead of double that number. From here this four-way method of powdering became gradually disseminated through the craft and is known in Europe as the American method.

It was about this time, 1882, that the method of producing photo-engravings in halftone by means of an intervening screen of fine lines, first practised by Talbot in 1852 and gradually improved by a number of later workers, was brought to the point of successful application by Georg Meissenbach in Munich. Two other commercially applicable methods of producing halftone photo-engravings had previously been worked out, one by our subsequent fellow-member, Frederick E. Ives, in this city, and the other by Charles G. Petit in Paris. The former had begun in 1878 to obtain his results by inking up the surface of a modulated relief, obtained by the gelatine wash-out method from a transparent positive, and pressing this down on a sheet of paper the surface of which presented lines or stipples embossed in relief. The lights of the picture being low in the gelatine relief and the shadows high, the embossed paper would be pressed out more or less according to the gradations of light and shade of the subject as represented by the modulated relief of the gelatine film. The process was later modified by inking the surface of the embossed lines or stipples instead of the gelatine relief and bringing the inked surface in contact with a plaster cast from the gelatine. In either case the resulting black-and-white halftone effect was photographed to obtain a negative, from which in turn the final printing plate was produced in the form of a photo-electro or stereotype. Petit's process was similar in all respects, except that he inked the surface of the plaster cast and then cut across it in a ruling machine with a V-shaped tool. As this cut deepest into the raised portion of the relief representing the lights of the picture and left the depression more or less untouched, there was produced an effect of halftone which was



ALPHONS LOUIS POITEVIN, 1819–1882.

then photographically reproduced in the form of a printing plate. These methods of obtaining halftone effects by mechanical means had been brought into practical use on a commercial scale when the greater facility and more perfect results of the optical method as realized by Meissenbach became generally recognized.

Talbot used a mesh of gauze or bolting cloth to produce optically a reticulated surface of his photo-engravings, but in his patent he mentions glass plates covered with fine lines or a grain of opaque powder as applicable for the purpose. About 1857, when Pretsch's halftone method was being worked commercially in London, the attention of a number of experimenters reverted to Talbot's indications, and some progress in that direction was made. In December of that year a French patent was registered by A. J. Berchtold for a method of halftone reproduction with a screen of parallel lines ruled on glass. A metal plate sensitized with asphaltum was first exposed under an ordinary negative and then under the screen successively in cross directions with gradually-diminishing exposures. Various modifications of this method were afterwards worked out, one by C. J. Burnet in England in 1858, and another in this city by Frederick von Egloffstein, patented by him in 1865. The screens used by the latter were made for him under direction of the noted steel engraver, John Sartain, by his son Samuel, afterwards also a leading worker in that art and subsequently and for many years treasurer of The Franklin Institute.

A further improvement was made by the brothers E. and J. Bullock, in England, their patent of November 17, 1865, describing a method of halftone reproduction by first making a transparent positive, putting over this a screen of gauze or other material, and then making a negative from the two together. They also describe a method of photographing the negative through a screen of parallel lines ruled on glass and placed in front of the sensitive plate. From these negatives they produced photo-lithographs and also zinc etchings by the transfer process.

Among other methods of halftone reproduction patented at that period was one by Joseph Wilson Swan, described in his English patent of July 6, 1865. This was based on the solubility of the unexposed parts of a chrome gelatine film,—that is, on the wash-out principle,—but included covering the surface of the film before exposure with a ruling of insoluble cross lines, or pro-

ducing these by transparent rulings on the positive or negative through which the exposure is made, and so retaining in the washed-out gelatine film a set of fine cross lines level with the surface. The dried gelatine relief was to be electrotyped and the plate printed as an intaglio or relief, according as a negative or positive had been used for the exposure. The method was unavailable, but pointed the way to possibilities which have latterly been realized in the so-called rotary photogravure process.

The earliest application of a photo-reproduction process in newspaper work was made in New York in 1873 in the production of the *Daily Graphic,* which was illustrated and printed by photo-lithography. Occasional supplements to this journal contained reproductions in halftone effects photo-lithographed by a method practised in New York by Leggo & Desbarets, including the application of a film of ruled lines between the negative and the sensitive plate. Some years later Swan obtained an English patent in which he describes a method of producing halftone negatives through a screen, the lines placed either before a transparent positive or before the sensitized plate in the camera, and turning the screen at an angle between each of several partial exposures of the plate. In 1882 the expedient of interrupted exposure through a screen of parallel lines was put into effective practice by Meissenbach through turning the screen only once—and that at a right angle—and this, combined with the improved process of zinc etching, which had come into use by that time, afforded results which marked an important era in the progress of the Techno-graphic Arts. I myself was at that time working to obtain halftone reproductions in grain effects by means of transfers from coarse-grained gelatine prints, and had put in a collotype press for the purpose. But the uncertainty of gelatine effects and the greater simplicity of the screen method pointed to the latter as the true direction of further effort. Meissenbach had transferred the screen of lines from between the negative and the sensitized metal plate to a more rational place between the copy and the camera. It remained to take the decisive step of transferring it back to a place within the camera in front of the sensitive plate, and this I soon concluded to do—not sooner, perhaps, than Meissenbach and others in Europe had done the same.

For a time the screen of single parallel lines extending diagonally across the plate and turned half way round during the

WILLIAM HENRY FOX TALBOT, 1800–1877.

exposure continued in use, though the application of a cross-lined screen with uninterrupted exposure readily suggested itself. I got practical results with such screens, composed of wire bolting cloth, as early as 1883, but the possibility of obtaining varied halftone effects with the single-line screen by varying the proportions of the divided exposure, coupled with the difficulty of getting a sufficiently perfect cross-line screen of any size, kept the single-line screens in use. These were generally produced by photographing a sheet of parallel lines printed from a steel plate or a lithographic stone ruled by machine, reducing the size to get closer rulings. But the clouding of the open lines through halation, which left those lines most transparent in the middle and gradually less so towards their edges, though apparently a desirable feature, proved in practice to be a hindrance, and even where the lines were cleared as much as possible these photographed screens kept out so much light as to necessitate a considerably prolonged exposure, and when doubled to make a cross-line screen the difficulty was correspondingly increased. The way forward was manifestly through a proper ruling on glass. To get this crosswise and to overcome the diffraction effect of surface rulings I conceived the idea of etching the ruled lines with hydrofluoric acid and blackening the depressions, which would give a theoretically perfect screen and a correspondingly perfect halftone reproduction. Small screens of this kind were put to use in 1887, and with the collaboration of my brother Max in this direction the idea was finally realized in full and patented by us in 1891.

Following these successive improvements of the halftone process, its uses and applications advanced by leaps and bounds. As early as 1890, in an article on this subject in the *American Annual of Photography* for that year, I found occasion to remark as follows:

"The influence of the halftone process in the dissemination of intelligence is already making itself felt in the pages of standard and current publications everywhere, and its value as an adjunct in raising the standard of art culture and of artistic appreciation is commensurate with its almost limitless possibilities. It is the graphic method of the future, combining as it does, in a higher degree than any other, the illustrative and the æsthetic elements of art."

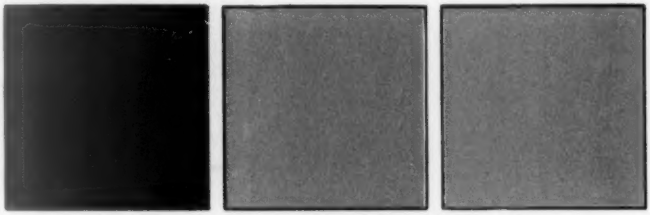
During the quarter century which has since elapsed two further advances of striking importance have been made in the application of halftone photo-engraving; namely, the three-color printing process and that of rotary photogravure.

The production of pictures in colors had become the special province of lithography, although for many purposes the greater rapidity and corresponding economy of printing from relief plates made this latter method preferable. In either case a considerable number of successive printings, in different colors from as many different forms, is necessary, and printers and lithographers working with colors have sought to reduce the number as far as possible. To some extent this could be done by printing one color over another to produce a third, and, by gradations of tone in each, bring about various tints of the combined colors. By combining in this way the three principal colors, red, yellow, and blue, a wide range of other colors and tints can be produced, the effect depending on the degree of skill with which the engraver or lithographic draughtsman works up the three different printing forms which make up the combination.

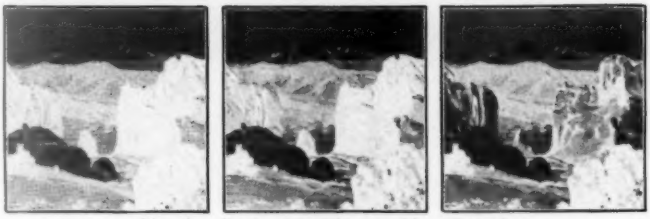
A very important advance in the production of color effects by photo-lithography is that known as the Polychrome process, patented in Europe by Henri J. Burger of Zurich, in 1897. In this process the printing forms, instead of being worked out by the lithographic draughtsman, are produced photographically, the negative of the subject, with all but the desired features stopped out, being used for one or two of the color forms, and transparent positives from the same negative, with the correlative features stopped out, being used for the other colors. A key plate from the original negative completes the effect. An essential feature of the polychrome method is the use of the asphaltum process to produce the printing form on the stone, the developed film presenting a very fine grain, corresponding with the gradations of the negative or positive applied in the exposure, and through which the stone is etched in preparation for the printing. This method is capable of producing effects of a high artistic quality and is especially applicable for subjects of large dimensions.

With the development of the halftone process the way was open for the production of relief-plate engraving by the three-color process of photography which had already previously been utilized, but only within the limitations of collotype and photo-

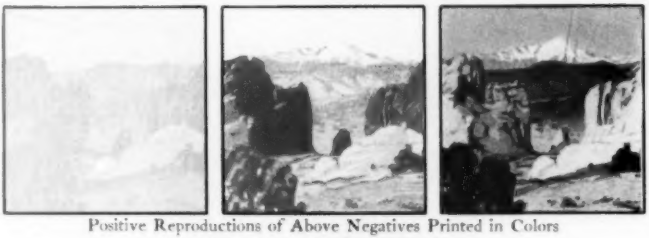
THE THREE-COLOR PROCESS



Glass Color Screens, Through Each of Which a Separate Negative Is Produced



Negatives Produced by Photographing Through the Respective Screens Above



Positive Reproductions of Above Negatives Printed in Colors Complementary to the Respective Screens

The Three Plates Printed Over Each Other

lithographic printing. In this process all the colors of an object are registered photographically on three separate negatives. One of these is photographed through a transparent screen colored orange red, so as to permit the sensitized plate to be affected only by those rays of light from the object which are contained in that part of the spectrum which includes the red and extends over the yellow to the green; the second is made through a filter screen colored green, so as to permit the passage of only the rays extending from the edge of the yellow over green to blue; and the third negative is made through a screen colored violet blue, which permits only those rays which are included in the remaining part of the spectrum to filter through and leave their impress on the sensitized plate.

These three color-separation negatives, together, therefore contain, in monotone, the effect of all the different colors of the object in all their various gradations of intensity; that is, in all the various tints of the respective colors from light color to full. By making these negatives through a halftone screen at the same time that the light is filtered through the color screen, they are made directly available to produce the print on metal for the etching process. Otherwise, it is necessary to make from each negative a print or transparent positive from which, in turn, the half-tone negative is made. The former is known as the direct, the latter as the indirect method.

As in each case the gradations of colored light are represented by corresponding gradations of darks in the halftone negative and, of course, by the reverse effect in the positive print from the halftone etching, it follows that the latter represents the colors and tints which were kept out by the color filter through which the negative had been made; that is, those complementary to that of the filter used. Accordingly the half-tone plate from the red filter negative is to be printed in blue-green, that from the green filter in magenta red, and that from the blue filter in yellow. By printing these one over another the effect of the combination is to reproduce, at least approximately, all the various colors and tints of the original. A supplementary plate, reproduced from a negative which represents the object as a whole, may be printed over the color combination in a neutral gray to make up for the shortcomings not only of the process itself but particularly of the printing inks in reproducing the true colors.

The technology of this process, like that of photography in general, may be traced back to the rise of modern chemistry in the seventeenth century, but its actual beginning is to be found in Newton's discovery in 1672, that white light is composed of rays showing all the colors of the rainbow, and that these in turn can be recombined into white light. This led to the idea of producing the entire range of colors by spreading one transparent pigment over another successively. Experiments in this direction, made by J. C. LeBlon, a copper plate engraver in Rome, from about 1720 to the time of his death in Paris in 1741, led to the conclusion that red, yellow, and blue were primary colors which, by proper combination, could be made to produce all the others. The researches of Thomas Young, published in 1807, afforded physiological reasons for assuming that the colors which could be so combined were red, green, and violet. Young's theory was subsequently strengthened by the investigations of Helmholz from 1856 to 1866, and practically confirmed by those of Clerk Maxwell during the same period. The latter, in 1861, was the first to actually demonstrate the possibility of obtaining a registry of all the colors of an object on three separate negatives photographed through three different color-filter screens, and thereby laid the foundation of the process of three-color photography.

The earliest practical application of this process was made about 1868–69 by two French photographers, Ducos du Hauron and Charles Cros, who, working independently, both produced their results by making with the gelatine wash-out process three pigment prints from the color-separation negatives, respectively in yellow, red, and blue, and laying these one over the other to complete the picture. A modification of this method was to make the gelatine wash-out prints in colorless films and color these with suitable dyes before combining them.

But much remained to be done to make three-color photography commercially available, principally toward increasing the sensitiveness of the photographic plate, especially to the less active color rays of the spectrum. A great advance in this direction was made by H. W. Vogel, in Berlin, in 1873, through his discovery of the efficacy of coloring the photographic plate with various dyes to increase its color sensitiveness. This opened a new field of investigation which was next explored by Cros, du

Hauron and Becquerel in Paris and at the same time by a noted member of this Institute, M. Carey Lea, in this city. Progress in this direction was made anew by Vogel in 1885, and greatly furthered by our distinguished fellow-member, Frederick E. Ives, in 1888. These advances brought three-color photography to a point where it was finding practical application in lithographic and collotypic printing, when the improvement of halftone engraving through the introduction of the engraved cross-line screen opened to the three-color process the far wider field of the typographic press.

More recently the halftone process has found a new application in the form of the engraving and printing method known as rotary photogravure. In this process an intaglio photo-engraving, instead of being produced on a flat plate to be printed from by the slow method of the copper-plate or steel-plate press, is engraved by the cross-line method on a copper cylinder and printed from by the far more rapid means of the rotary press. For such printing the ordinary method of inking intaglio plates, which consists of forcing thick printer's ink into the hollows of the engraving and wiping off the surface before each impression, is impracticable. Instead of that, the inking is done by the method used in the printing of textile fabrics and wall-paper from copper rolls. This is effected by covering the surface of the engraved cylinder with a thin liquid ink of any desired color, which flows into the hollows of the engraving and is cleared from the surface by means of a scraper, known in the trade as a " doctor," leaving the ink in the hollows, from which it is taken up by the paper as it passes over the rotating cylinder under pressure from above.

Like all intaglio engraving and printing processes, the rotary photogravure method is capable of producing very fine effects, but, as the engraving must be cylindrical and requires a special method of printing, the process cannot be economically applied except where large editions are to be printed off, and it is consequently available mainly for use in the pages of illustrated periodicals of large circulation and for pictorial supplements to daily newspapers.

A method of engraving copper cylinders by the halftone process and applying them in the manner of textile printing was patented in Germany in 1904 by Eduard Mertens and developed

by him for newspaper illustration in Freiburg in 1910. The engraving on the copper cylinder was produced as a halftone intaglio, in a manner similar to that on flat plates which I took occasion to bring before the Institute in 1892 and which is described in the JOURNAL of September of that year. By that process the gradations of light and shade are made up, as in halftone relief plates, by differences in the size of the dots and stipples produced by the cross-line screen, the intervening depressions, which receive the printing ink, being of uniform depth. In the grain photogravure process, on the contrary, the gradations of light and shade are produced by graduated depths of the engraving, which accordingly receive the ink in quantity varying with the depth instead of the breadth of the depression. Such plates require that the depressions be produced with a roughened or grained bottom so as to hold the ink, which, for that purpose, must be quite thick, and the textile printing method with thin ink cannot therefore be applied with them.

A method of overcoming this obstacle appears to have been worked out in London some time before 1900 and employed there commercially, in great secrecy, under the name of "Rembrandt" intaglio printing. The main features of this process, which gradually came into general use, were the production of the engraving on the cylinder as an intaglio etching with graduated depths, and producing this intaglio with a network of thin cross lines. These are provided for the purpose of holding the scraper or "doctor" on the surface of the intaglio, the liquid ink left by the scraper being held in the interstices between the crossings in quantity varying with the depth of the etching. The result is produced by exposing a wash-out gelatine film under a transparent positive of the picture, then exposing it again under a line screen, but using one of transparent cross lines instead of the normal halftone screen of opaque cross lines. The exposed film is then placed on the copper cylinder and there developed by washing out, or it may be developed on paper like a carbon print and transferred from that to the surface of the copper. The metal is then etched with iron perchloride, which penetrates the dry film more or less, according to the varying thickness of the undissolved gelatine, and bites into the surface to correspondingly varying depths. The cross lines of undissolved gelatine, resulting from the exposure through the

transparent screen, shield the metal surface uniformly, leaving a corresponding network of thin cross lines in the etching.

Thus the method of producing photo intaglio engravings with surface cross lines, which Swan patented in 1865 and which proved impracticable, and the two early methods of producing photo-engraved printing rollers, that of Pretsch in 1855 and that of Woodbury in 1872, which also were impracticable, have been replaced by methods which recent advances in the art have made effective for the purpose.

Among the many other new applications of techno-graphic art which have latterly been developed, at least one more calls for consideration; namely, the offset printing process. This is virtually a new way of printing, not of engraving, but it falls properly within our present purview, if only because, in connection with this newest method of printing, a new use has been found for the oldest method of photographic reproduction, Niépce's asphaltum process of 1824.

In the offset printing process the impression on the paper is not made directly from the form itself, but indirectly from a print of the form on an intervening medium, from which, in turn, it is offset on the paper under pressure; hence the name of the process. Any printing surface from which prints can be obtained in any of the usual ways is applicable for the purpose.

Offset printing is really a development of the old process by which decorative designs printed on paper are transferred to pottery. Since about 1880 this method of transferring by offset has been in use for the printing of lettering or decorative designs on tin plates or other rigid surfaces, usually through lithography. Essentially the method consists of printing the inked form on the surface of a comparatively soft cylinder, usually a covering of soft rubber on a metal roll, and from that to the material, paper, fabric, metal, or what-not, which is to finally receive it. The printing on metal plates is usually effected in the flat press, the plates taking the place of the printing form on the bed of the press and the form in turn being replaced by the soft impression cylinder, which first receives the print from a cylindrical printing form, stereo- or electrotype, and then offsets it on the metal surface.

From about 1890 this process began to be applied to printing on paper, principally by lithographic transfers in cylinder presses adapted for the purpose. A notable advance in offset printing was

made by Ivan Orloff at the Russian Imperial Printing Office, in St. Petersburg, through his invention of a press specially designed for the purpose and patented in 1897. This press, as exhibited at the Paris Exposition of 1900, was adapted for printing in colors from relief plates fixed on several cylinders, the successive impressions from which were first printed in registry on a cylinder of soft rubber and finally transferred from that to paper. But it is only during the last ten years, since the offset press came to be materially improved, that this method of printing has come largely into commercial use. During the same period the field of offset printing has been extended through the use of halftone reproductions applied from photo-lithographs or etched plates and latterly from photographic prints on zinc plates by the asphaltum process. This affords a greater delicacy of impression in being printed on the rubber cylinder, and is giving the offset process increasing importance among the techno-graphic arts.

Many, indeed, and widely ramifying have been the advances of the pictorial and printing arts during these recent years, and never before have they been applied so universally as now. They have become, more than ever before, not only an expression of the culture of the time, but the most powerful agency of its further progress. The great educational movement of our modern day, which is so fast changing the complexion of the social structure, has its most efficient vehicle in the printing press, and through no other influence has that efficiency been so greatly reinforced as by the development and recent advances of the techno-graphic arts.

BIBLIOGRAPHY.

The literature bearing on the development of the techno-graphic arts is widely spread through publications of scientific societies, the records of patent offices, the pages of numerous technical periodicals and of a long list of special treatises and collated works, a citation of which would surpass the limitations of the foregoing review. The "History of Photography" (*Geschichte der Photographie*) by Dr. Josef M. Eder, the eminent director of the Royal-Imperial Institute of the Graphic Arts, in Vienna, published in 1905, and forming the first volume of his "Complete Handbook of Photography" (*Ausfürliches Handbuch der Photographie*), contains numerous references to the original data of the subject, and to this the present writer is largely indebted.

THE ESTABLISHMENT OF PHOTOMETRY ON A PHYSICAL BASIS.*

BY

HERBERT E. IVES, Ph.D.,

Physical Laboratory, The United Gas Improvement Company.
Member of the Institute.

SYNOPSIS.

1. Introduction.
2. The basic idea of the physical photometer.
3. The method of visual colored light photometry.
4. The development of practical physical photometers.
5. The question of luminous efficiency.
6. The mechanical equivalent of light.
7. The fundamental standard of light.
8. Discussion.
9. Definitions.
10. Summary of work accomplished, and statement of that still remaining.

1. Introduction.

When we "turn on" an electric lamp we supply it with power, and we get (among other things) light. The power supplied we measure with simple instruments which indicate by the

* This paper was prepared, on invitation, for the International Electrical Congress at San Francisco. On the abandonment of the Congress publication in this JOURNAL was arranged for.

The practical physical photometer described under section 4 is clearly the same instrument as that described by W. W. Coblentz in the September issue of this JOURNAL. Every detail of this photometer was worked out by the writer and Mr. E. F. Kingsbury. It was exhibited and described to Dr. Coblentz on the occasion of his two visits to our laboratory during the past year. It has been shown as well to numerous other visitors, for several of whom incandescent lamps and colored glasses have been measured. The device was described before the American Physical Society at its New York meeting, October, 1914, and the complete description has been in the hands of its journal, *The Physical Review*, since April. Its use forms one of the recommendations made by the writer to the Illuminating Engineering Society (*Trans. I. E. S.*, vol. x, No. 4, p. 315, June 10, 1915) which are now under study at the Bureau of Standards on behalf of that society. H. E. I.

position of a pointer on a scale. Our unit, the watt, is directly and simply connected with the fundamental units of length, mass, and time.

When we undertake the measurement of the light produced the procedure is not so direct. We have recourse to a device called a photometer, which indicates by other means than the automatically moving pointer so popular in many kinds of measurement. In the photometer are comprised another lamp, means for varying the amount of light from that lamp, and a "photometric field," which is an optical arrangement specially designed to use the light-sensitive part of the apparatus—the human eye—at its maximum sensitiveness. The movement of the pointer is done by the human hand, according to the dictation of the eye. When its position is read upon the scale of the instrument a measurement is obtained which, under a certain definite condition, compares favorably in accuracy with other kinds of measurement. This condition is that the lights under comparison are of the same color, as in the case of a gas flame and a pentane lamp. When, however, we depart from this condition of similarity of color the same accuracy cannot be claimed; we enter what is still, in fact, debatable ground in photometry.

Having made a measurement under those restricting conditions where satisfactory accuracy is possible, we express the result in a unit—the candle—which, while definite and carefully maintained, has no simple or direct connection with the excellent system of units now in use in other branches of physics and engineering. In short, as the current goes past the switch its measurement passes into a territory but partly developed and still under the sway of the inconvenient and the arbitrary.

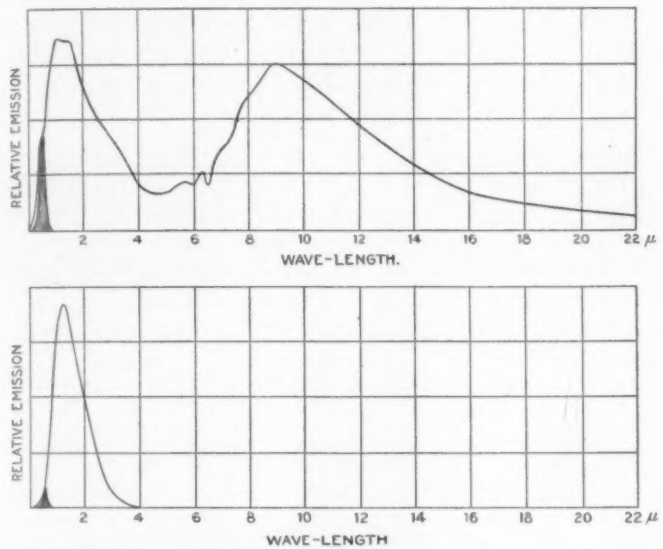
The goal of physical photometry is to make the measurement of light as simple as the measurement of power, and to express the result in the same unit—the watt.

The attainment of this goal is possible only through the coördination of extensive investigations in two separate branches of science; namely, physics and physiological optics. It is the object of this paper to bring together in one place such a summary of these investigations as will give a clear idea of the success thus far achieved in placing photometry on a physical basis.

We shall first outline the basic idea of the physical photometer. Then a review will be made of the investigations in visual colored

light photometry whose completion is a necessary preliminary to successful physical photometry. Considerable space will then be given to a description of the actual development and use of satisfactory physical light-measuring instruments. After this an apparent digression will be made to the study of physical means of evaluating the efficiency of light production. Through this we shall arrive at an idea of the relationship between what the physical photometer and the visual photometer measure.

FIG. 1.



Complete spectra of Welsbach mantle (upper diagram) and tungsten lamp (lower diagram).
Small cross-hatched areas = luminous flux.
Ratio of cross-hatched areas to total areas = radiant luminous efficiencies.

The numerical factor connecting the present unit and the watt will be discussed under the head of "The Mechanical Equivalent of Light." The proposal that the watt is the rational unit of luminous flux then follows.

2. The basic idea of the physical photometer.

Of the power supplied to a light source, part is dissipated as heat by conduction through burner, leading-in wires, or supports. Part is dissipated by convection of heat through the atmosphere surrounding the light source. A third part is dissipated in the

form of radiant heat or electromagnetic waves through the ether. In all of these forms the power is measured in the same unit, the watt.

We are primarily concerned with the radiated power, for it is a portion of that which we measure as objective light, and express at present in a unit called the lumen, derived from the candle.

The radiation from a light source, when passed through a dispersing apparatus, such as a prism, is resolved into a spectrum. In Fig. 1 are shown in diagrammatic form the complete spectra of two representative illuminants, a Welsbach mantle and a tungsten lamp. The radiation consists of a large portion of invisible and a small portion of visible rays. The visible radiations have widely varying capacities to illuminate or to rouse the sensation of light in the brain. These varying capacities are roughly represented by the small curves enclosed in the visible parts of the spectra. They represent the relative brightnesses of the different parts of the visible spectra of these illuminants.

The basic idea of the physical photometer is readily grasped from this figure. It must be an instrument capable of measuring radiation, and it must respond to each of the spectral radiations in proportion to their luminosity; that is, it must not respond at all to the invisible radiations, it must respond most to the radiations at the middle of the visible spectrum, in the yellow-green, and progressively less toward the red and blue at each end.

It is at once clear that the foundation of the physical photometer is a knowledge of what is called the luminosity curve of the spectrum. If the physical photometer measures the different parts of the spectrum in proper relative value, it will measure correctly lights built up out of the spectrum; that is, all lights. The method of determining this luminosity curve must now be outlined.

Before proceeding to this the problem of the physical photometer may be made clearer by a comparison with the human eye. Now the eye behaves in respect to the luminosity factor of radiation exactly as though it consisted of a retina sensitive to all kinds of radiation, before which is interposed a colored absorbing medium opaque to the greater part of the radiation spectrum, and most transparent to the middle of what we call the visible spectrum. It is the task of the constructor of the physical photometer to substitute for the retina some other medium sensitive to radia-

tion, and to place before it an absorbing medium which shall transmit the different radiations in the same way as the hypothetical medium over the retina. This absorbing medium may be pictured as a spectrum template, through which the various radiations pass, each being reduced in passage to its appropriate value as light.

3. The method of visual colored light photometry.

The determination of the spectrum light template or luminosity curve is a problem capable of solution only after a method is developed for evaluating the luminosities of radiations of different colors. The simple comparison of two radiations as in ordinary photometry becomes inexact and unsatisfactory immediately the radiations are different in color. The difficulties of colored light photometry are several. It is, first of all, impossible for the eye to appreciate anything save exact similarity or lack of that. It can not, for instance, tell how many times one surface is brighter than another. Now when the lights to be compared are different in color the condition of exact similarity can never be attained. Consequently it is difficult to decide when two colored areas are equally bright. Many observations, extending over an extended interval of time, are necessary. Another difficulty lies in the fact that the relative luminosities of different colors change with the intensity. Blue becomes relatively brighter, red darker, as the illumination is decreased. Still another difficulty is met, due to the variation of relative brightness with the size of the areas viewed.

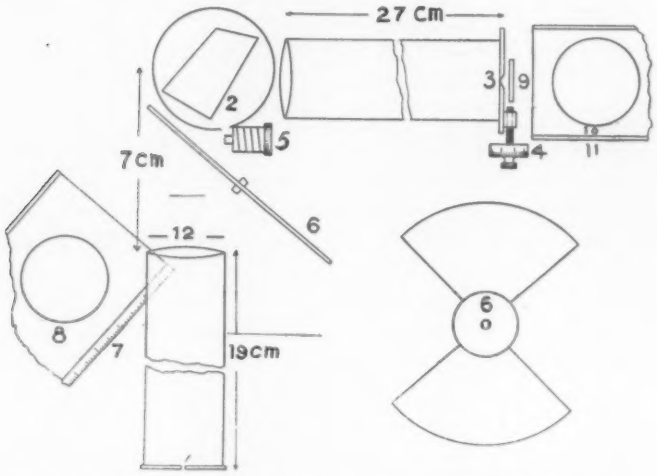
These difficulties are met by the individual observer. When we are interested in more than one individual, we meet with difficulties due to differences between individuals. No two people see colors of exactly the same relative brightness, and their differences range all the way from trivial ones to the serious ones accompanying color-blindness. No matter what method of colored light photometry is used, it is essential that a sufficient number of observers be employed so that the results may be truly average. We have recently found that the number necessary to establish an average value is about fifty, none of the fifty having any marked abnormalities of color vision.

We therefore find in the difficulties of colored light photometry some of the greatest obstacles to be surmounted before physical

photometry may be realized. But at the same time we find a weighty additional call for such an instrument. The services rendered by an instrument which measured differently colored lights as easily as ones of the same color and could as well embody the characteristics of the average eye, and thereby dispense with the need for a large squad of observers, would be far greater than those of the instrument usually first thought of; namely, a convenient substitute for the eye in ordinary photometry.

Preceding the work on the physical photometer proper, an

FIG. 2.



Flicker photometer arranged for obtaining luminosity curves of the spectrum.
1, Observing slit; 2, prism table; 3, collimator slit; 4, divided drum; 5, wave-length drum; 6, white sector desk; 7, photometer bench; 8, standard lamp; 9, diffusing glass; 10, light source; 11, photometer bench; 12, diaphragm.

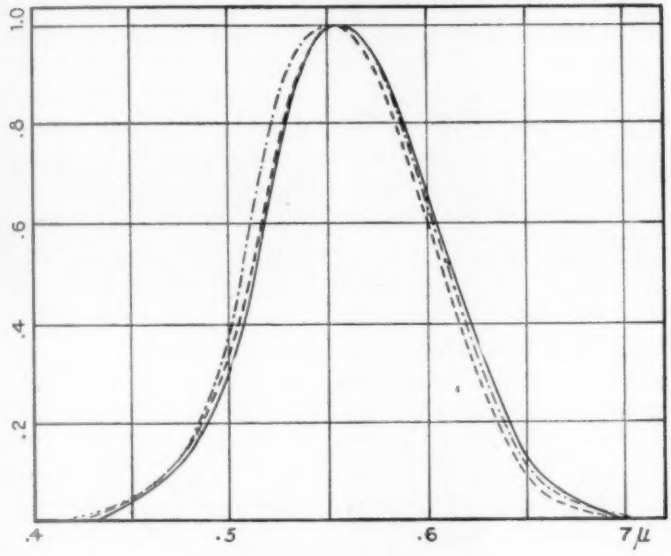
extensive investigation of colored light photometry was carried through.[1] From it was developed a special photometric method. By this photometric method determinations have been made of the luminosity curve of the spectrum, using a large number of observers. In addition a group of test colors has been evaluated, the whole constituting the establishment of a luminosity scale, similar in some respects to the temperature scale with its fixed points.

The photometric method adopted as the basis of this work involves the use of the flicker photometer at a certain illumination,

with a definite size of the photometric field. In addition, and quite as important, it calls for a large group of observers.

In Fig. 2 is shown diagrammatically the flicker photometer as arranged for obtaining the luminosity curve of the spectrum. It consists essentially of a spectrometer to provide the various spectral radiations, and a disk half transparent to allow the colored light to reach the eye, and half diffusely reflecting the light from a fixed light source. When slowly rotated this disk performs the

FIG. 3.



Luminosity curves of the spectrum.
Dot and dash line . — . — curve as determined by Ives.
Dash line — — curve as determined by Nutting.
Full line —— curve demanded for agreement between visual photometry and physical photometry. (Transmission curve of absorbing solution used in thermopile artificial eye.)

function of alternating the colored and standard light; it is, in other words, a flicker photometer. When the spectral light is made of a certain intensity no flicker is produced by the process of alternation, and the spectral and other light are equally bright upon the flicker photometer criterion. This criterion has been decided, on the basis of the research which preceded, to be the most satisfactory one.

One more measurement is necessary; namely, the amount of radiant power represented by the colored light. What is required

ultimately is the relative brightness of spectral radiations of the same power value, or the luminosity curve of the equal energy spectrum, as it is called.

In Fig. 3 are shown two luminosity curves of the spectrum obtained in this way, each involving about twenty observers, and differing in the way in which the value of the radiant energy was obtained. They show the brightest part of the spectrum to lie in the yellow-green.

It should be possible, with the luminosity curve thus determined, to proceed at once to the physical photometer. The fact that these curves differ somewhat, that the sources of error are rather large, and that it is now known that a still larger number of observers is really necessary, suggested the desirability of establishing the values of other color differences, more easy to fix accurately, and which could be measured by a sufficient number of observers to meet our criterion for being "average."

We have, therefore, determined by the same photometric method, using a group of 61 observers, the transmissions of a number of inorganic salt solutions, representing a series of steps from nearly monochromatic light to the kind of color differences found in practical photometry of illuminants.[2]

When the actual problem of developing the physical photometer was reached we were, as a consequence of this preliminary work, in a very different position from any who had previously attempted the same task. We had what they had not—adequate means of determining whether the physical photometer performed satisfactorily when made; in other words, whether it read *right*.

4. The development of practical physical photometers.

Thus far two different means have been worked out for producing a light template to go in front of the radiation measuring instrument. The first of these, which may be characterized as a mechanical device, will be described under the title of "a precision artificial eye."[3] It is a delicate laboratory instrument fitted to be the final reference standard. The second instrument, also an artificial eye, is much simpler and less delicate, at a slight sacrifice in absolute precision. It is a practical instrument for the average physical laboratory.

The "precision artificial eye" consists essentially of a spectrometer which forms a spectrum of the light source. This

spectrum is then passed through a mechanically cut template, whose aperture at each wave-length is exactly proportional to the luminous value of that wave-length of radiant power. By means of a condensing lens this spectrum is recombined into a small image of the prism face, and allowed to fall upon the receiver of a small vacuum thermopile of high sensibility. The thermo-electric current is measured by means of a Thomson galvanometer of the most sensitive type. This current is proportional to the *light* entering the slit of the instrument.

FIG. 4.

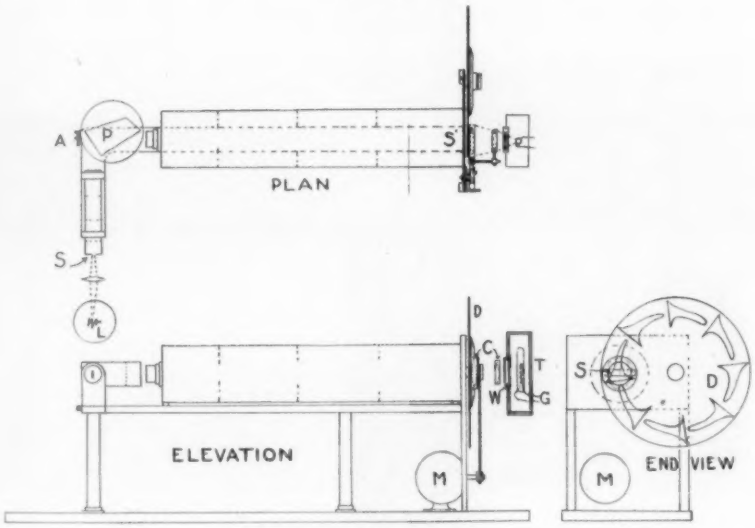


Diagram of precision artificial eye.

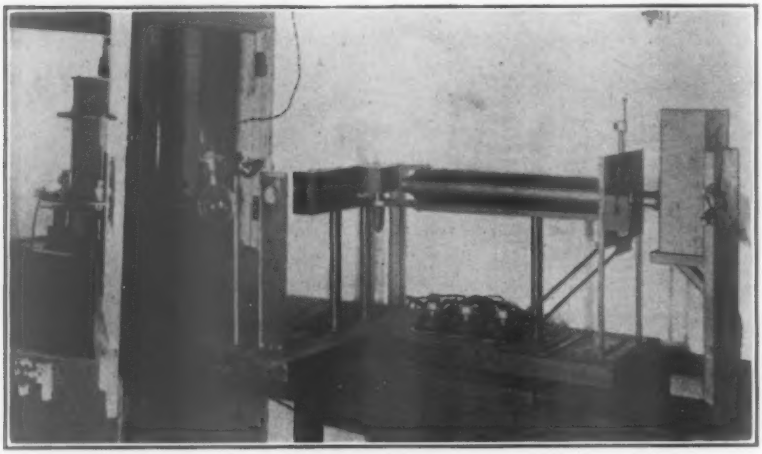
L. Light source.
S. Slit.
P. Prism.
A. Adjusting screw.
S'. Point of formation of spectrum.
C. Condensing lenses.
T. Thermopile.
D. Spectrum template.
G. Galvanometer leads.

The instrument as constructed is shown diagrammatically in Fig. 4 and by means of a photograph in Fig. 5. The light from a lamp (L) passes through a condensing lens, which focuses it upon the slit (S). A spectrum is formed at S', in which plane lies the light template, which may be either a rotating disk, as shown in the diagram, or, in some cases, a fixed opening as shown in the photograph, in either case the opening being cut accurately to the shape of the spectrum luminosity curve as determined by the standard photometric procedure. The spectrum as recom-

bined by the convex lens system falls upon the thermojunction (T), from which leads go to the galvanometer.

The term "precision" applies to this instrument for the reason that its design permits the exact copying of any luminosity curve, either experimentally found or embodied in some mathematical formula. It is thus qualified to be the final instrument of appeal in the standardizing laboratory. It has, however, its limitations, as all sensitive instruments have. The light measured must be of considerable intrinsic brightness, because the process of spectral resolution and recombination is very wasteful of light. The thermopile and galvanometer sensibility must be very high—about

FIG. 5.



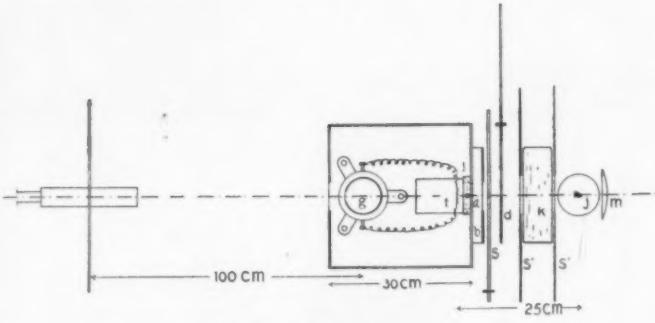
Precision artificial eye.

of the order of magnitude necessary to measure the radiation of the stars. The practical effect of these limitations is that the device is best used for measuring not light sources themselves, but auxiliaries used in light measurement, such as absorbing screens of various colors by means of which color differences may be eliminated in practical photometry. This function is all that is at present really necessary in a precision artificial eye, but it is to be expected that in time such greater sensibility can be attained that more varied needs can be directly taken care of.

The second instrument to be described is also a thermopile artificial eye,[4] which, however, differs from the first in being much

simpler and more generally practical. Its essential feature is the use of an absorbing solution in place of the mechanically cut spectrum template. This absorbing solution should have a transmission at each wave-length proportional to the luminous efficiency of that radiation. It will be readily grasped that the attainment of an exact copy of the spectrum luminosity curve by the transmission of one or a mixture of several absorbing media is a task of no small magnitude. In so far as this must merely be an approximation must this form of physical photometer fall short of being a precision device. Nevertheless, it has been found possible to copy the luminosity curve very closely indeed and so construct a physical photometer of this type, which is now in almost daily use.

FIG. 6.



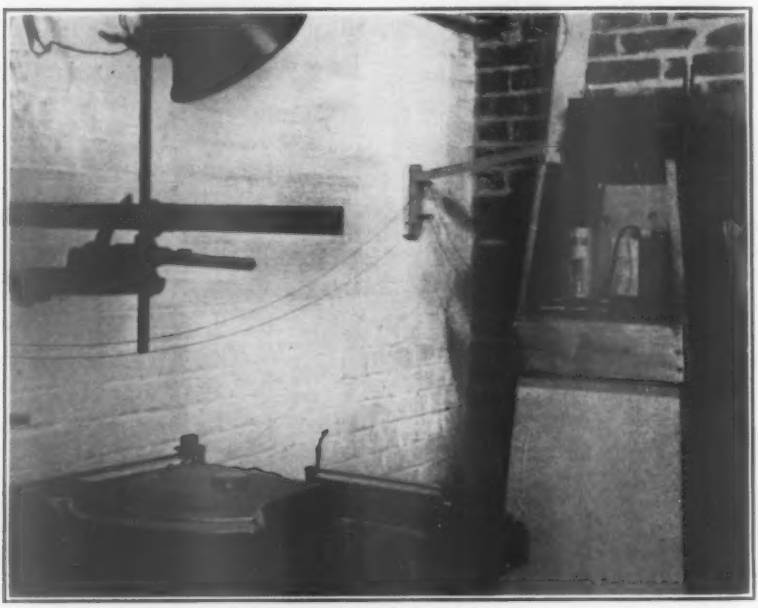
Physical photometer.

t. Thermopile.
g. Galvanometer.
l. Luminosity curve solution.
s. Shutter.
d. Sector disk.
s'. Screens.
k. Water tank.
j. Light source.
m. Concave mirror.

Fig. 6 shows this instrument diagrammatically. The radiation from the light source passes through the "luminosity curve" solution (*l*) to the surface thermopile (*t*), which is connected to a sensitive d'Arsonval galvanometer whose deflections are read by the telescope. A water tank (*k*) is used to prevent the luminosity curve solution from becoming heated, and to completely exclude such infra-red as the solution (*l*) transmits, and various screens and shutters are added, as shown, whose purpose is obvious. In its essentials, however, the instrument is extremely simple, as is its operation. A photograph of the apparatus is shown in Fig. 7.

The heart of the device is, of course, the luminosity curve solution. In the evolution of the instrument a screen was first developed closely copying one of the experimentally found luminosity curves. This was then tried out with the test colors which had been measured by our large group of observers. Of these test colors, which have been mentioned before, two may be taken as typical. These, which we shall speak of hereafter merely as "the test colors," are a yellow and a blue absorbing solution which, when placed over a standard lamp, should measure equal.

FIG. 7.



Photograph of physical photometer.

We have developed these primarily as a criterion for the selection of groups of observers who should have the same average characteristics as our large group of 61.[2] The physical photometer must, of course, measure these test colors as the average eye does by the visual photometric method. On test the first luminosity curve solution did not do this exactly. A certain displacement of the luminosity curve was called for, indicating that the luminosity curve of our large group of observers was different from that obtained in the direct determinations of this curve—due either

to an actual difference of the two groups, or to errors in the direct determination caused by the experimental difficulties. The shift called for was made by varying the relative proportions of the constituents until the test colors (and other test colors) measured exactly as they were determined by the visual method.

The constitution of the final luminosity curve solution is as follows, for one centimetre thickness:

Cupric chloride	60 grammes
Cobalt ammonium sulphate	14 grammes
Potassium chromate	1.9 grammes
Nitric acid (1.05 gr.)	18 c.c.
Water to	1 litre

With this must be used a protective water tank of at least 2 cm. thickness.

The spectrum transmission is shown in Fig. 3.

The characteristics of this physical photometer may be summarized thus: It measures by the simple motion of a pointer over a scale the relative luminous intensities of lights of different color with a precision comparable with the best visual photometry, and the result is the same as would be given by the mean of a very large group of observers using the best visual method.

The only important limitation to the instrument as it stands is that the luminosity curve solution is only a close approximation. It has been tested out on all the ordinary color differences among illuminants for which it will be used, but should be used with caution for other color differences. In other words, it should be compared in that case with visually determined values or with the precision instrument above described. It is to be expected that a further study of absorbing media would result in a still closer approximation to that spectrum luminosity curve which shall be decided upon as standard.

The present practical limitation to the physical photometer is its comparatively low sensibility. It is distinctly a laboratory instrument. Its chief use lies in the calibration of colored light standards for use outside the laboratory by ordinary visual photometry, with the color differences thus artificially eliminated. It is not, perhaps, too much to hope that means will be found in course of time to increase the sensibility of radiometric devices to an extent which will make the physical photometer an instru-

ment available even in street-light photometry. An attractive possibility is some form of amplifier similar to the amplifying devices used for wireless telegraphy receivers.

5. The question of luminous efficiency.

The previous section has described how the process of light measurement has been made similar to, and nearly as simple as, the ordinary measurement of voltage, current, or power. But the contributions of the spectrum template conception to light measurement are not exhausted with that step. A satisfactory means of measuring the efficiency of light production is also furnished. This will now be described, partly because of its intrinsic importance, partly because it serves as an excellent mode of approaching the question of a rational standard of light.

By the efficiency of a piece of mechanism is universally understood the ratio of output to input, of useful work to power applied. If all the applied power is returned by the machine as useful work the efficiency is 100 per cent. It is a prerequisite to the expression of efficiency on a percentage basis that both input and output be measured in the same units.

Lighting science has been behind other branches of engineering in this matter, because there has been no percentage basis of comparison. We have been able to say, by comparing the lumens per watt of one illuminant with the lumens per watt of another, what their relative efficiencies are, but whether they are intrinsically efficient transformers of power into light is not indicated.

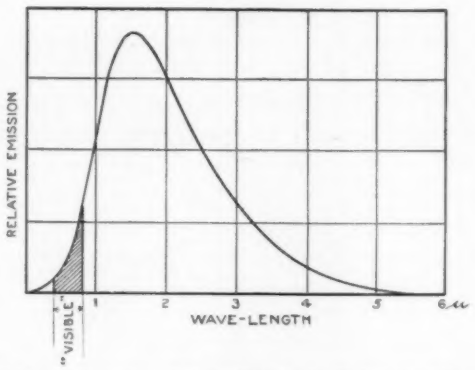
Curiously enough, there are two measures of luminous efficiency to be found in the literature of lighting. Each has one good point and one bad. The common physical measure of so-called "luminous efficiency" is illustrated by Fig. 8. It consists in the ratio of the "visible" radiated energy to the total radiated energy. By "visible" is meant a certain portion between rather arbitrary limits in the red and violet portions of the spectrum. This ratio, which is with more propriety called the "visible fraction" of the radiation, gives only the crudest sort of idea of light-producing capacity, for it gives just the same weight to the deep red and violet parts of the spectrum, which are comparatively non-luminous, as to the most luminous part in the green. On this basis two illuminants many times different in illuminating power could rank as equally "efficient." The one good point

about this method is that this " visible fraction " is expressed in percentage values.

The engineering measure of luminous efficiency is " lumens per watt," a true comparison of useful output (namely, illuminating power) with input. But, as already indicated, this is on a scale whose bottom is known (zero), but whose top is not. Consequently it is not on a par with the simple percentage figure in which we can express the efficiency of a transformer.

What is called for is a measure of efficiency which shall apply the percentage scale to the measurement of true lighting usefulness. Such a measure is supplied by utilizing the spectrum luminosity template.

FIG. 8.



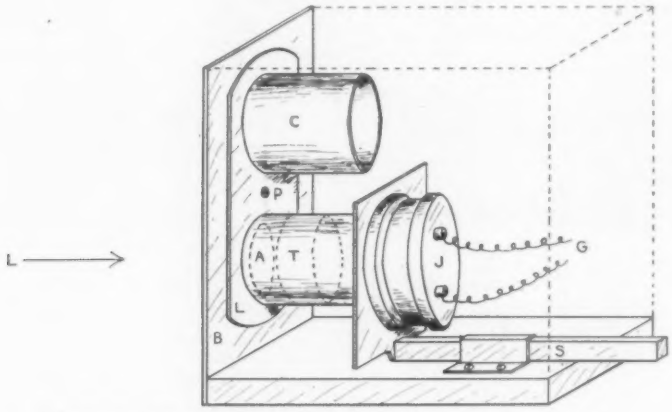
The "visible fraction," formerly called the "luminous efficiency" of the radiation of an illuminant.

Consider first the evaluation of the efficiency of the *radiated* power. We have already seen that the power which is transmitted through the visual luminosity curve screen of the physical photometer is directly proportional to light. If now we measure as well the radiation *without* interposing the luminosity curve screen, and compare the two quantities, we have a ratio of illuminating power to radiated energy. The relative values of this ratio from one illuminant to another are exactly as their relative lumens per watt. We have, in short, a measure of relative efficiency of light production.

But one step is needed to make this an absolute measure of efficiency. What value is given in such a measurement to the radiation of highest possible efficiency of light production? It

obviously depends on the absolute transmission of the luminosity screen at the wave-length of maximum efficiency (0.56μ). If this transmission is *unity* the most efficient radiation will measure 100 per cent. by this procedure. Let us define such a luminosity curve screen of maximum transmission unity as an *ideal luminosity curve screen.* The measurement of the luminous efficiency of any radiation then becomes simply the measurement of the ratio of the radiation transmitted by the ideal luminosity curve screen to the total radiation. Efficiencies are expressed on a percentage scale whose unit is the most efficient possible radiation.

FIG. 9.



Instrument for measuring the luminous efficiency of any radiation.

L. Radiation entering instrument through aperture *A*.
J. Thermopile connected to galvanometer by leads *G*.
C. Unobstructed tube.
T. Tube containing luminosity curve solution.
L. Plate, pivoted at *P* so that either *T* or *C* may be placed before *J*.
The radiation from the light source is first measured entire, as it passes through the unobstructed tube *C*. It is then measured after passing through the luminosity curve solution *T*.

Recently Dr. E. Karrer [5] has made a series of measurements of radiant luminous efficiencies in accordance with this idea. The luminosity curve screen used was similar to that described in connection with the physical photometer. To reduce the results to those which an ideal screen would give it was only necessary to divide the measured value through the screen by the maximum transmission of the screen and to make some small corrections, due to the small variations of the actual screen's transmission curve from the shape of the ideal one.

Fig. 9 shows a complete arrangement for measuring the

luminous efficiencies of the radiant power of illuminants upon this rational basis. In Table I are some representative values of ordinary illuminants. It is to be noted how excessively low are the efficiencies—only a few per cent.—of our best artificial light sources even when we consider only that portion of the applied power which has already been converted into radiation.

TABLE I.

Radiant Luminous Efficiencies of Light Sources.

1. Standard "4-watt" carbon lamp	0.0045
2. Vacuum tungsten lamp, 1.25 w. p. c.	0.0165
3. Welsbach mantle, 0.75 per cent. ceria	0.012
4. Open gas flame	0.0019
5. Nernst glower, 8-ampère	0.0108
6. Nitrogen-filled tungsten lamp, 0.65 w. p. c.	0.029

Attention has purposely been given so far only to the luminous efficiency of the radiation, but our interest is as great, or even greater, in the *total efficiency* of a light source; that is, the efficiency of utilization of the applied power. This is immediately arrived at by a knowledge of the efficiency of the transformation of the applied power into radiation. The ratio of the watts radiated to the watts applied may be called the *radiation efficiency*, and, both applied power and radiated power being measured in the same units (as they should be), this ratio is a straight percentage. We then have, quite simply, that the total efficiency of a light source is the product of its radiation efficiency by the luminous efficiency of its radiation. The full significance of this is shown by considering the case where all the applied power is transformed into radiant power with no loss, and this radiant power is in the form of yellow-green light (wave-length 0.56μ). The radiation efficiency is 100 per cent.; the luminous efficiency of the radiation is 100 per cent.; hence the total luminous efficiency is 100 per cent. In short, we have developed, through the use of the ideal luminosity curve screen idea, a measure of the efficiency of light production in which the unit is the most perfect possible transformation of the applied power into light. The measurement of luminous efficiency is thus made exactly parallel with the measurement of other efficiencies.

In order to get actual values of total luminous efficiencies it is only necessary to have a set of values of radiation efficiencies

to multiply by the values of radiant luminous efficiency in Table I. As a matter of fact, no extensive measurements of radiation efficiencies are on record. Consequently the values of total luminous efficiency which have been obtained thus far have been arrived at along a slightly different road.

It has been pointed out that one reason for the chaotic state which has held in regard to luminous efficiencies is that power input and useful work (light) are commonly measured in different units. Most of our data on the efficiencies of illuminants are in the form of lumens per watt. If in place of the lumen we could use the watt to measure light we would have a ratio of watts to watts; that is, a fraction or percentage. In the next section it will be shown that this can be done. The value of the lumen in watts of luminous flux will be found, and by substituting this for the lumens in the lumens per watt values figures will be obtained for total luminous efficiencies.

6. The mechanical equivalent of light.

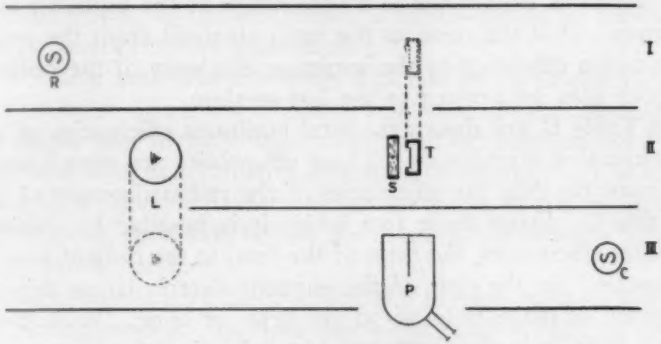
What is here to be defined as "the mechanical equivalent of light" can best be understood by asking: "What does the physical photometer equipped with an ideal luminosity screen actually measure?"

Consider a light source, supplied with a certain number of watts of power, of which a certain proportion are radiated and are received either by the eye or by the physical photometer with the ideal screen. That which reaches the retina and has been evaluated as light, as though it passed through a hypothetical luminosity curve screen, we measure in lumens. That which reaches the radiometer and which has been evaluated according to its light value by a concrete luminosity curve screen we have as yet not considered describing in any definite unit. We only know that it is always exactly proportional to the lumens. Now ordinarily radiant power incident on a radiometer would be measured in the standard power unit, the watt. Let us call the watt of radiant power which has been evaluated as light by an ideal luminosity curve screen a *watt of luminous flux*. We then measure the same radiation in lumens by using a visual photometer, and in watts by using the physical photometer. These two being always proportional, it follows that the lumen is some multiple of the watt of luminous flux.

The "mechanical equivalent of light" is here defined as the number of watts of luminous flux in the lumen.

A recent investigation has been devoted to the determination of the value of this constant. Two different methods were used, of which only one need be mentioned here. The general principle is to measure the same radiation both in lumens and in watts of luminous flux. The apparatus (very much the same as the simple physical photometer and the luminous efficiency meter) is shown diagrammatically in Fig. 10. The radiation from a light source

FIG. 10.



Apparatus for determining the mechanical equivalent of light.

R. Radiation standard.
T. Thermopile.
S. Luminosity curve solution.
L. Light source.
C. Luminous standard.
P. Photometer head.

I. Position of thermopile for determining sensibility of thermopile-galvanometer system (watts per square metre per centimetre deflection).
II. Position of thermopile and light source for measuring luminous flux, in watts per square metre.
III. Position of light source for measuring luminous flux, in lumens per square metre.

falls upon one-half of a photometer field, and is evaluated, by approved photometric methods, in lumens per unit area. The light source is then moved so that its radiation falls on a radiometer, over which is an ideal luminosity curve screen. The intensity of the radiation is registered, after which the radiometer is exposed to the radiation of a standard of radiation. This gives the equivalent in watts of the previous measurement. We then have the value of the same radiation in lumens and in watts of luminous flux, from which their ratio is at once derivable.

The experimental determination fixes the lumen as having a value of 0.00159 watt of luminous flux.[6]

The first use to be made of this figure is the calculation of

total efficiencies of light production. We have but to take the efficiency of an illuminant in lumens per watt and transform the lumens to watts of luminous flux, by multiplication by 0.00159, to obtain the ratio:

$$\frac{\text{watts of luminous flux}}{\text{watts of applied power}}$$

From our method of defining the watt of luminous flux it follows that in the case of the most efficient possible transformation of applied power into light one applied watt yields one watt of luminous flux. The ratio just given, therefore, expresses total luminous efficiencies as a percentage of the highest possible efficiency. It is the same as the ratio obtained from the product of radiation efficiency by the luminous efficiency of the radiation, to which idea we arrived in the last section.

In Table II are shown the total luminous efficiencies of some representative illuminants. These efficiencies are even lower, as they must be, than the efficiencies of the radiated power as given in Table I. From these two tables it is possible to obtain the radiation efficiencies, the ratio of the total to the radiant luminous efficiencies. In the case of the vacuum electric lamps this is of the order of magnitude of 90 per cent. or over. With the gas mantle light it is about 16 per cent., showing the large part of the applied power lost by convection and conduction of heat.

TABLE II.[1]

Total Luminous Efficiencies of Light Sources.

1. Standard "4-watt" carbon lamp	0.0042
2. Vacuum tungsten lamp, 1.25 w. p. c.	0.013
3. Welsbach mantle, 0.75 per cent. ceria	0.0019
4. Open gas flame	0.00036
5. Nernst glower	0.0077
6. Nitrogen-filled tungsten lamp, 0.65 w. p. c.	0.026
7. Yellow flame arc lamp	0.072
8. Quartz mercury arc lamp	0.068
9. Carbon arc, D. C.	0.019
10. Acetylene flame	0.0011

7. *The fundamental standard of light.*

The common discussion of standards of light, to be found in text-books on photometry, deals with the mechanical charac-

teristics of certain illuminants, which for one reason or another have been selected as custodians for the unit of luminous flux. We have, for instance, the sperm candle, the Hefner lamp, the pentane lamp, etc. By adhering closely to certain specifications as to dimensions and to certain requirements of chemical composition of the fuel, these standards are reproducible from specifications. That is, however, their only claim to be called standards. Actually the luminous flux unit of this country is maintained by sets of incandescent electric lamps, not reproducible from specifications, but of proved permanence of characteristics when properly handled. The problem of *maintaining* a unit is, in fact, in excellent shape, but the unit which is maintained is of dimensions fixed by history rather than science.

We have seen that luminous flux can be measured in watts, and that by so doing the efficiency relationships are taken care of in a simple and orderly way. The question now arises: "Why is not luminous flux properly measured in watts?" The answer is that it is; the only reason other units are in use is that they became established long before the relationship between light and power was understood.

The proposal here made is that the present units of luminous flux be superseded. In their place *the watt should be adopted as the unit of luminous flux.*[8]

By so doing lighting science can be placed on the same absolute basis as other physical sciences, removing it from its present anomalous position.

The transition from the present unit to the new one is (apart from commercial considerations) quite simple. The present unit maintaining standards need merely have new values assigned to them differing from the old in the ratio of 0.00159 (the mechanical equivalent of light). The greatest difference will be in the method of checking these standards with the fundamental quantity. Instead of founding our work on certain arbitrary conditions of fuel combustion, reference will be made to a standard of radiation, which is one of the regular physical standards, maintained for a variety of uses. *Any* light source which gives one watt of radiation through an ideal luminosity curve screen is giving one watt of luminous flux or one light watt. It is, therefore, necessary to maintain the standard of radiation, and to have the ideal luminosity curve screen (or a screen very closely ideal from whose results

the ideal can be readily calculated). The watt standard of luminous flux is then based on a physical specification; and a physiological one, which is the simplest analysis of which it is capable.

It is to be noted that there are two alternative, but exactly equivalent statements of this logical unit; namely, one watt of radiation of maximum possible luminous efficiency, or $\frac{I}{L}$ watts of radiation of luminous efficiency L.

8. Discussion.

A word may be said on the simplifications introduced by the adoption of the light watt. At present an anomalous condition exists in the manner of describing the characteristics of illuminants. Formerly light sources were commonly described as of so many candle-power, which is different in every direction. Approved practice now dictates that a lamp should be described by the amount of light flux it gives; that is, by the number of lumens.[9] This practice has not been at all widely followed, largely because the lumen appeals to most as an additional, not-well-understood and confusing unit. The practice with regard to electric lamps has been to hold to the well-known unit, the watt; but the only watt which has been measured is that of the power supplied. We thus find incandescent lamps described, not by what they give but by what they use. A 100-watt lamp is one consuming 100 watts. To find what light it gives we must have another figure: its lumens per watt, or specific consumption.

In other branches of engineering it is common to specify a machine by what it gives. A ten-kilowatt engine gives ten kilowatts, and its efficiency is so much. By the use of the light watt illuminants may be similarly specified without introducing a new term. A two-watt lamp will be one that furnishes two light watts. Its efficiency shows how many watts of applied power are necessary to yield the light.

The fact that the most efficient illuminants we now have will thus be denominated by a low figure in light watts, but will necessitate the expenditure of forty or fifty times that amount of applied power, may be unpopular with illuminant manufacturers, but will render a decided service if it spurs them still

more to improvements in the most wasteful of all technical processes of power utilization—light production.

It is perhaps not out of place to say a word on the subject of the probability of this new unit being generally adopted. It is, of course, always extremely difficult to displace anything well established, no matter what its shortcomings. An exactly parallel case is furnished by the metric system of weights and measures. The most that has been accomplished thus far in this country, aside from scientific fields, is to legalize its use. The relations between the old arbitrary system and the metric have been definitely established and legally recorded. The transition from the old to the new system can be made as fast as the public wants it made. In a similar way the light watt might be recognized as a legal unit, connected by a definite constant of proportionality with the present practical units. It might, with the rest of the metric system, be used in scientific work with the hope of its ultimate practical adoption. The fact, however, already noted, that the adoption of the light watt will actually appear as a simplification, because it does away with some names now necessary and peculiar to photometry, may promise an earlier adoption than has been vouchsafed to the centimetre and the gramme.

9. Definitions.

In this rapid review of the topics included under physical photometry it has been impossible to avoid the occasional loose use of certain terms, or the assumption of considerable previous knowledge on the part of the reader. In order that the various quantities and relationships may be available in exact and rigid form, the following list of definitions is given. These definitions are all in harmony with the physical methods here described, and include as well quantities of use in the transition from the present arbitrary units to the ones proposed.

Power consumed by a light source $= P$; expressed in watts, a portion of which is dissipated by radiation, the remainder by conduction and convection.

Power radiated by a source $= R = \int_0^\infty R_\lambda \, d\lambda =$ power emitted by a light source in the form of radiation between wave-lengths 0 and ∞, expressed in watts.

Radiation efficiency $= \frac{R}{P}$ = ratio of the power dissipated as radiation to the total amount of power consumed by the source. (A pure numeric.)

Luminous flux $= F$ = radiant power evaluated according to its capacity to produce the sensation of light.

Light evaluating factor or stimulus coefficient of any radiation is the ratio of the luminous flux, in its appropriate units, to the radiant power producing it, in its appropriate units.

The luminous efficiency of any radiation $= L_R$ = the relative capacity of the radiation to produce the sensation of light, compared with the capacity of the same quantity of radiation of the maximum possible light-producing capacity. (A pure numeric.)

The luminous efficiency of any radiation is the mean value of the luminous efficiencies of its component monochromatic spectral radiations. These latter are specified by the luminosity curve of the normal equal energy spectrum, of maximum value unity. The spectral luminosity curve is obtained by the standard photometric method for colored light photometry.

To a close approximation the spectral luminosity curve is represented by the expression:

$$L_\lambda = A\left(\frac{R_1}{\lambda}e^{1-\frac{R_1}{\lambda}}\right)^\alpha + B\left(\frac{R_1}{\lambda}e^{1-\frac{R_2}{\lambda}}\right)^\beta + C\left(\frac{R_3}{\lambda}e^{1-\frac{R_3}{\lambda}}\right)^\gamma$$

where

$A = 0.999$	$R_1 = 0.556$	$\alpha = 200$
$B = 0.04$	$R_2 = 0.465$	$\beta = 400$
$C = 0.095$	$R_3 = 0.610$	$\gamma = 1000$

Total luminous efficiency of a light source $= L_T$ = the relative capacity of the power applied to a light source to produce the sensation of light, compared with the capacity of the same quantity of power in the form of radiation of maximum possible luminous efficiency. (A pure numeric.)

Units.—Luminous flux is connected to radiant power by a numerical evaluating factor. The unit of power is the watt. The present arbitrary practical unit of luminous flux is the lumen. The light evaluating factor or stimulus coefficient is consequently expressed in lumens per watt. If for this evaluating factor is taken the *luminous efficiency* as above defined, the unit of luminous flux

is the same as that of radiant power or applied power; namely, the *watt*.

In the symbols proposed:

$$P \times \frac{R}{P} \times L_R = P \times L_T = F.$$

In order to go over to the watt as the unit of luminous flux it is necessary to know the:

Mechanical equivalent of light—the value of the lumen in watts of luminous flux.

(The lumen is approximately 0.00159 watt of luminous flux or light watts.)

(The terms "specific consumption," "specific output," etc., involving relationships between watts and lumens, are superseded by the method of defining luminous efficiency, and by the adoption of the watt as the unit of luminous flux.)

The quantities derived from luminous flux (*e.g.*, illumination, luminous intensity, and brightness) are to be defined as at present, with the necessary substitution of the watt of luminous flux for the lumen wherever occurring. It is suggested that the new unit of luminous intensity on the watt basis might be called the "pyr."

10. Summary of work accomplished and statement of that still necessary.

This paper summarizes a series of investigations extending over several years, having for their object the simplification and rationalization of light measurement.

A physical photometer or artificial eye has been developed to practical form, whereby the results of an average eye may be obtained, with almost the simplicity of the measurement of voltage or current. The measurement of the efficiency of light production has been put on a rational basis. A new unit of light flux is proposed, through the use of which photometry is made a part of the centimetre-gramme-second system. The value of this unit in terms of the present one has been determined.

No research is final, and it is but proper to point out in what way this one may be carried to still greater usefulness.

The primary object of the work was to establish methods. In this it has been eminently successful. At the same time every effort was made to obtain numerical results of value. The value

of these numerical results is somewhat less than that of the methods, and for obvious reasons. As the work progressed from stage to stage additional light was thrown on the parts previously completed. It was found, for instance, from work done near the end, that a much larger number of observers was necessary for the determination of the spectral luminosity curve than had been thought necessary at the time that part of the research was done. It was found, too, that a curve different from the experimentally-found one was clearly called for. The luminosity curve finally decided on is actually determined only by the transmission curve of a certain inorganic salt solution. These shortcomings do not affect the validity of the methods, but they prevent the results from claiming the highest accuracy. A repetition of the numerical determinations by the same methods, but profiting by the experience obtained in the present study, should establish the constants of physical photometry with a high degree of accuracy.

Before such a repetition is undertaken, however, it is of extreme importance that the foundation of it all, namely, the spectrum luminosity curve of the average eye, be determined with the very highest accuracy possible, using an adequate number of observers. This is a task which would be most appropriately undertaken by such an organization as the Bureau of Standards.

A question frequently raised in this connection is whether it would not be feasible simply to adopt as standard some luminosity curve of the spectrum, either an experimentally determined one or a simple mathematical curve, and thereby dispense with the need of further experiment. The answer to this is that if *all* photometry were done physically any curve could be agreed upon. Since, however, a certain amount must be done visually, and the final criterion of usefulness is visual, the necessity for *agreement* between visual and physical must be met. As to how close this agreement need be, or whether a certain compromise may not be permissible when the agreement has reached a certain stage, there is room for debate. In the present work the luminosity curve used in the physical photometer has been altered from the directly determined ones in order to make the visual work the final criterion. At an appropriate time this process could, if desired, be reversed. The precision artificial eye could be equipped with a legally adopted curve with which the values of the test colors could be established. Observers for visual work could then be

selected who would measure the test colors in this new ratio instead of the visually established one. The complete scale would then be established by the determination of the mechanical equivalent of light on the basis of this curve, a simple matter by the method described. Or the transmission of some solution might be adopted for the standard luminosity curve, and a similar process gone through. It would, for instance, be perfectly feasible to take the test-color ratio, as determined by a solution matching the luminosity curve determined by the author, which is only two or three per cent. off the present mean visual ratio, and base the selection of observers for visual work on this ratio. Obviously this could not be done if the disagreement between the two methods of approach was greater than the range of variation to be expected in any ordinary group of observers. Hence the need for a pretty close agreement between the various modes of approach before such a partly arbitrary solution to the problem may be seriously considered. The agreement between the visually established scale and the physical one here used is quite good enough to form the basis of such a resort to legislation (for instance, by the technical societies and government bureaus). The further work indicated would, however, in the writer's opinion, be ultimately called for by the increasing demands for accuracy in technical measurement.

Physical Laboratory,
United Gas Improvement Company,
Philadelphia, May 20, 1915.

REFERENCES.

[1] Ives, "Studies in the Photometry of Lights of Different Color," *Phil. Mag.*, July, Sept., Nov., Dec., 1912.

[2] Ives and Kingsbury, "Experiments on Colored Absorbing Solutions for Use in Heterochromatic Photometry," *Trans. Ill. Eng. Soc.* No. 8, 1914, p. 795. "Additional Experiments on Colored Absorbing Solutions for Use in Heterochromatic Photometry," *Trans. Ill. Eng. Soc.*, 1915, No. 5, p. 253. "Flicker Photometer Measurements on a Green Solution," *Phys. Rev.*, March, 1915, p. 230. "On the Selection of a Group of Observers for Heterochromatic Measurements," *Trans. Ill. Eng. Soc.*, 1915, No. 3, p. 203.

[3] Ives, "Precision Artificial Eye," *Phys. Rev.*, 1915.

[4] Ives and Kingsbury, "Physical Photometry with a Thermopile Artificial Eye," *Phys. Rev.*, 1915.

[5] Karrer, "A Method of Measuring Radiant Luminous Efficiencies," *Phys. Rev.*, March, 1915, p. 189.

[6] Ives, Coblentz and Kingsbury, "The Mechanical Equivalent of Light," *Phys. Rev.*, April, 1915, p. 269.

The value now given differs by two per cent. from the one given in the paper just quoted. This changed value results from the application to the original data of two corrections; one, that due to the adoption of the luminosity curve called for by the physical photometry investigation, in place of the Nutting curve; two, that due to the elimination of the effects of an infra-red transmission band in the luminosity curve solution originally used. On the assurance of Dr. Coblentz, who collaborated as radiation expert, that no such transmission band could be present, much time and study were given to the harmonizing of the two sets of data comprising the experimental part of that investigation, which was finally arrived at by the adoption of the Nutting luminosity curve. Extended work with the physical photometer later showed clearly that this curve was unsatisfactory, and at the same time proved the necessity for the additional protection of a considerable depth of water, indicating an infra-red transmission band to be present after all. Very fortunately, a simple measurement of the luminous efficiency of a "4-watt" lamp with the old unprotected and the new correct solution gives at once the correction to be applied. As a result of this measurement we find the net result to be the justification of the new luminosity curve and the two per cent. correction above noted. The agreement of the various mechanical equivalent measurements is even better than as originally published; the final value may lay claim to high accuracy.

[7] Ives, "The Total Luminous Efficiencies of Present Day Illuminants," *Phys. Rev.*, May, 1915, p. 390.

[8] Ives, "The Primary Standard of Light," *Astrophysical Jour.*, Nov., 1912, p. 322.

[9] The description of a light source by its total light flux (as recommended by the Illuminating Engineering Society) is not to be interpreted as a criticism of the common laboratory practice of confining measurements of intensity to a single direction. The factory examination of incandescent electric lamps by the measurement of their horizontal candle-power, or the measurement of the quality of illuminating gas by the luminous intensity of a flame in a certain direction, are illustrations of a general laboratory procedure adopted to reduce to a minimum the actual labor of measurement. This procedure consists in investigating the property on which information is desired by determining the value of some easily-measured factor to which the property in question bears a constant and known ratio.

RECENT PROGRESS IN MILITARY AËRONAUTICS.*

BY

LIEUT.-COL. SAMUEL REBER,

In charge of the Aviation Section, Signal Corps, U. S. A.
Member of the Institute.

THE first decade of the twentieth century has added to the mechanical engines of war two types of apparatus, one heavier than and the other lighter than air. While the rigors of warfare will be apparently increased by their use, they will prove potent factors in the disappearance of war from the forum of the world as the ultimate means of arbitrament for international controversies. The application of mechanical flight to warfare is but an added proof of the maxim of the German strategist who said, "War is the only science that lays under tribute all other sciences." Any progress in mechanical arts that tends to shorten the duration of a war, even by increasing the destructive potentiality of its implements, is a real gain to humanity, and the discoverer of a process or the inventor of an engine which increases its horrors and destruction is a real benefactor to mankind, since the increased loss of life and property will certainly cause civilized nations to hesitate and seek other less drastic methods for the settlement of international differences before final appeal is made to the arbitrament of arms. The art of mechanical flight has extended the domain of warfare into three dimensional spaces, has created new means of observation, communication and attack, whose potentialities are now but partially realized by the great military powers, whose existence has brought into being a new arm of the service, and whose utilization has produced great changes in the military and naval policies of the great powers.

As sea power has been one of the dominating factors controlling the policies of great powers in the past, air power will be so in the future. The moral effect of the presence or absence of an efficient air force will be a deciding factor in hostile operations, and the commander who is without an efficient air fleet will be at a great disadvantage from the outset of operations, and will have

* Presented at a joint meeting of the Mechanical and Engineering Section and the Aëro Club of Pennsylvania held March 26, 1914.

the celerity and certainty of his movements greatly hampered by the feeling that his plans and disposition of his forces are known to his opponent through aërial reconnaissance. To achieve success without an aërial force, he must greatly outnumber his opponent. Information of the location and movements of the enemy are absolutely essential to any commander. Such information is usually obtained by the active use of cavalry in contact with the enemy or by secret service within his lines. An efficient air force will not only supplement but anticipate the reconnaissance work of the cavalry, and can penetrate miles beyond the line of contact, provided it is not opposed by similar and better aircraft of the enemy.

The two best examples as to what might have happened had an army been supplied with a fourth arm were in the recent Russian-Japanese war. Had the Russian commander had an aërial reconnaissance force at his disposal, it is more than probable that the results of the two decisive battles of Liao Yan and Mukden would have been entirely different. Had Kuropatkin checked the Japanese advance on the Tai-tse-ho in September, 1904, the outcome of the war would have been much more favorable to Russia. On Aug. 25, 1904, the Japanese attacked the Russian position in front of Liao Yan, and on the 27th the Russians, after an obstinate defence, retired to a second position, which was attacked without results until the 31st, when Oyama decided to send the first army under Kuroki to turn the left wing of the Russian position. On the 31st of August and 1st of September, Kuroki's army moved to the northeast and separated itself completely from the main position by a distance of ten miles. This movement was absolutely unknown to the Russian commander and, by its attack on the 2d of September, so relieved the situation along the main front that the Japanese advance, which had been completely arrested by the Russians, was renewed and Kuropatkin compelled to retire along the railroad to prevent his army being cut off from its line of communication. Kuropatkin's information had led him to believe that he was outnumbered at the beginning of the engagement by the Japanese, while, in fact, he had a decided superiority in men and guns. It must be evident that a few hours of aërial reconnaissance would have disclosed the real state of affairs and indicated the isolated position of Kuroki on September 1, and given Kuropatkin a splendid op-

portunity to capture or defeat with ease the entire first army. Again, in front of Mukden, Kuropatkin was unaware of the arrival of the third army, and even of the existence of the fifth army, nor did he have any information as to the extensive flanking movement of the third army from the 21st of February to the 1st of March, which movement ultimately compelled his withdrawal from his fortified lines. One single speed scout could have started from Kuropatkin's headquarters, circled the country over which the flanking movement was made, and returned and reported the movement within an hour and a half.

The functions of aircraft in war are fourfold: reconnaissance, both strategical and tactical; the prevention of similar reconnaissance on the part of the enemy; for communicating purposes, and for destructive action against the enemy.

The strategical reconnaissance by aircraft will cover all operations for the acquirement of information as to the location and movements of the enemy, and also of the terrain. When the reconnaissance becomes tactical in nature, as for example during an engagement, it will ascertain the location and disposition of the opposing troops, especially the reserves, and artillery positions, and inform the artillery commander of the effect of the fire of his guns. Whether reconnaissance will be made by dirigibles or aëroplanes will depend upon the available aëronautical material at the disposition of the commander general, the weather conditions, and the special object of the particular reconnaissance. For long-distance work, and especially for over-sea operations, the dirigible possesses certain desirable features, especially as part of the work is to be done at night. For the prevention of reconnaissance on the part of the enemy, there will be required types of fighting machines which can carry light automatic guns and possess a greater climbing ability than those of the opposing force.

For communication purposes the aëroplane is especially suitable. The conditions of modern warfare—the large extent of territory over which forces operate, and the length of the line of contact in a modern battle—render it extremely essential for the commanding general to have the swiftest means of communication, which is best furnished by aëroplanes.

The use of the aëroplane and dirigible for destructive operations offers a large field in the attack by explosives from overhead of permanent works, depots of supplies, dockyards, rail-

roads, cities, and troops in position, but in the latter case the effect will be more moral than physical. A squadron of dirigibles or aëroplanes can compel a blockading fleet to remain a safe distance away from the shore, keep it constantly in motion, and cause greater coal consumption—a dominating factor in naval operations.

The possibilities of destructive aërial attack are well given in the following extract from a recent paper on aërial warfare by an officer of the French Army, Lieutenant Sensever:

"We shall see later on the possible utilization of the German aërial fleet for the destruction of works of art, arsenals, stations, or the direct struggle against enemies terrestrial or aërial. For the destruction of a city no problem of target practice arises; all shots count; the target is vast; no projectile is lost; no problem of defence is necessary for the aërostat, because in the night time it is invisible; no cannon can reach it; no aëroplane can pursue it; it is heard, but cannot be seen. Let us imagine on the evening of the declaration of war the ten Zeppelins, now in service, set forth with lights extinguished at an elevation of 1000 metres towards Paris. The compass, the luminous signals of the stations and railroads, the lights of the cities are guides which indicate the direction to an aërostat more clearly, in fact, by night than by day. In the silence of the country, in the nocturnal quietude after the sounds of the city, the distant roar of the motors will vanish, leaving behind it incertitude. What is there to do? The Zeppelins steer towards Paris. In four hours, if there be no wind, they will cover the distance which separates the Rhine from the French capital. Now they are above Paris, whose innumerable lights mark out the quarters, the squares, the avenues; then it is very simple. When each one arrives at its appointed spot, it accomplishes its task of destruction and death: to one, the stations where our soldiers will embark to-morrow; to another, the Ministry of War, the Elysée; to others, the forts or barracks at Versailles or Vincennes; to others, the Opera, the Louvre, Notre Dame, the Arc de Triomphe—all our glories and our forces! In a few minutes each Zeppelin has discharged its four or six bombs of 600 pounds each, in all about 50, or about 30,000 pounds of trinitrotoluol, which will level the beautiful quarters, which will kill millions of sleeping people, which will destroy gas mains, sowing conflagration and confusion in the terrorized city. Dur-

ing these few moments the Germans, from their nacelles, will contemplate their work—this spectacle that Nero never dreamed of. Then they will take their journey towards the east. At daybreak they are resting in their hangars along the Rhine, ready to start out again to-morrow."

The above is not an idle speculation, but could happen if the French are unprepared to meet the invasion of their frontiers through the air. England has this same menace threatening her across the North Sea.

Since the beginning of the twentieth century aëronautics have been used in three wars: the Russia-Japanese, the Bulgarian war, and the Turko-Italian, and in minor expeditions of the French and Spaniards in Africa. The dirigible had not been sufficiently developed, and the aëroplane was not in existence in the Russia-Japanese war, in which the Russians used captive balloons to advantage for observation purposes and for the direction of their artillery fire. The Japanese, though in possession of a balloon train, made practically no use of it during the war, though at Port Arthur there was an excellent opportunity for its use in locating the Russian fleet. Had the Japanese used a captive balloon the fleet could have been easily located and the siege expedited without the terrific loss imposed upon them by the capture of 203 Metre Hill, from which they obtained a view of the harbor and the ships. In the Turko-Italian war in Africa the Italians used both dirigibles and aëroplanes. These dirigibles, P–2 and P–3, only 4100 metres in size, made in all 91 flights, and P–3, engaged in the battle of Zanzur, discovered and routed a force of Turko-Arabic cavalry by dropping bombs. These dirigibles, assisted by aëroplanes piloted by Italian officers, were of the greatest value for reconnaissance purposes, and, though frequently exposed to hostile fire, escaped without material damage.

In the Balkan war it may be said that practically no effective use was made of aëroplanes by any of the belligerents, as they were entirely unprepared for this class of service. In the first war the Turks had two in front of Kirk-Kilissé which were broken down and did not fly. They had some others in the rear which were not used until after the Bulgars reached Chataldja. The Bulgars had no trained aviators, and were compelled to hire foreigners, who rendered them practically no service. The

advantage to the Bulgars of a single aëroplane is illustrated by that period of loss of contact, October 24 to 27, 1912, when the Bulgarian cavalry broke down and they had no knowledge of the Turkish position.

At Adrianople the Turks had no aëroplanes. The Bulgars used a number which were mostly manned by foreigners. General Ivanoff summed up their use as follows:

"The best that can be said for the aëroplane is that the flights showed what great service they are capable of if well manned."

The Servians, while having four aëroplanes, did not put them in service. At Chataldja a number of flights were made for the Turks by foreign aviators, and the Greeks made several reconnaissance flights in their operations.

The lesson from the Bulgarian war is that material cannot be obtained and military aviators trained after the opening of hostilities, and that foreign or civilian aviators cannot be depended upon for efficient service. Experience has shown that for military aviation the pilots as well as the observers must be trained soldiers.

The first really successful ascent of a dirigible was made in September of 1884 by the "La France," built by Captains Reynard and Krebs. This balloon was only 51 metres in length, with a cubic capacity of 1864 metres, and driven by a 9-horsepower electric motor, giving it a speed of 14½ miles per hour. It was not until the beginning of the twentieth century that the French began the development of the present non-rigid type of balloon and added this to their military forces. The Germans, whose attention was drawn to the remarkable progress made by the French since the beginning of the century, began the development, under Count Zeppelin, of the rigid type of balloon. Experience has developed three separate types: the rigid, the semi-rigid, and the non-rigid, each possessing certain advantages and disadvantages for military purposes.

The rigid type is composed of a rigid frame of aluminum or wood in whose interior are a number of gas bags. The frame is covered by a light, permeable material, and the nacelles, carrying the motors, equipage, and crew, are attached to the frame. The Zeppelins have a frame of aluminum, and the Schutte-Lanz and Speiss types of wood. The envelope of the semi-rigid is completely flexible, and its form is maintained by the pressure of

the inclosed gas, while the weight of the nacelle and the equipment is distributed along the envelope by means of a keel or longitudinal girder, as in the Gross, Lebaudy, and the Italian military dirigibles and those of the Forlanini type.

In the non-rigid the nacelle is directly suspended from the envelope, as in the Astra Torres, Parseval, Clement-Bayard, Zodiac, and the Siemanns-Schukert.

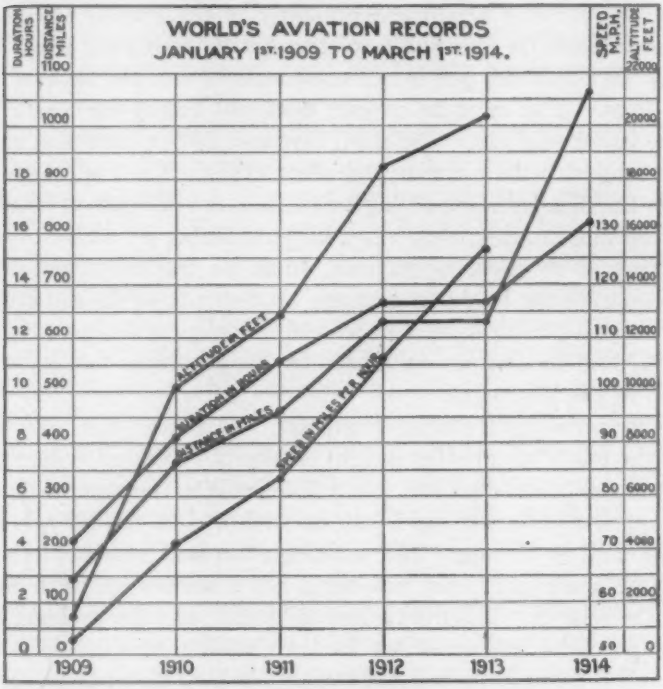
The rigid type possesses the advantage of greater speed, more inherent stability, and, on account of the construction, the possibility of carrying armament not only in the nacelle but on the upper surface; is less liable to damage from hostile fire, owing to the fact that the gas is not contained in one but several separate bags. The rupture of one does not cause the loss of the entire volume of gas. The rigid carries a larger crew and can remain longer in the air than the other types. The rigid type possesses the disadvantage of high cost, is more difficult to handle in starting and landing, requires a larger number of trained men in handling it in these operations, must be housed when not in motion, is more liable to damage or destruction in unfavorable weather, and more liable to accident, usually total destruction, in making bad landing, as evidenced by the accidents that have happened to the Zeppelins.

The semi-rigid offers a greater resistance, has less speed than the rigid but greater weight economy for equal volume, and is more easily handled and much less liable to damage in landing. It, as well as the non-rigid, can be anchored in the air when not in use, and is transportable, although the keel renders it less so than the non-rigid. The non-rigid has a slower speed in the air than the semi-rigid, is the easiest to handle, has the greatest economy of weight, and possesses the least liability to damage in landing, and is easily repaired and transported. The tendency is towards two types: first, the large, rigid, armed cruiser type, with a radius of action of 500 miles and an endurance in the air of thirty or forty hours. This type is assigned to permanent stations along the frontiers, with a zone of observation and defence. The second is a small, non-rigid type for over-sea operations. The Germans have developed this type of balloon more rapidly than the French and English, as it seems to be part of the German policy to offset England's supremacy on the seas by a German supremacy of the air. There are under construction in Ger-

many dirigibles of this type up to 30,000 cubic metres capacity, with a lifting power of fifteen tons.

Since what may be called the real beginning of aviation in the year 1909 (Fig. 1), the records indicate a tremendous development in speed, distance, duration, and altitude. The relative importance that the various great powers have attributed to aëronautics in war may be inferred from the following (Fig. 2),

FIG. 1.

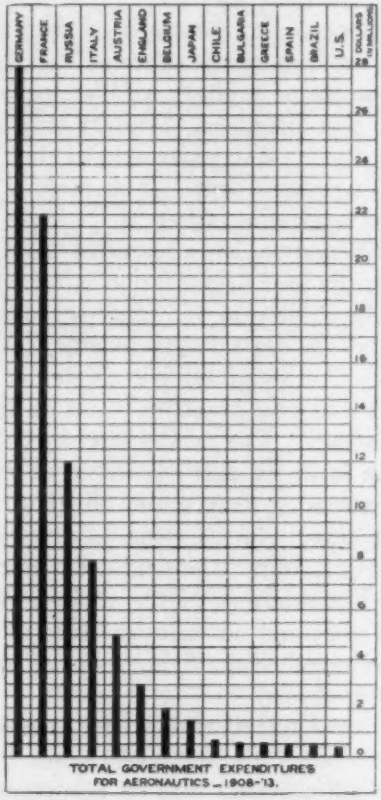


which shows the amounts of money expended by them during the past five years ended in August last.

Our own country was the first to realize the military importance of the aëroplane, and in 1907 the War Department issued specifications and proposals covering the construction of an aëroplane for the military service. In 1908, in the trials at Fort Myer, Va., due to an unfortunate accident, Lieutenant Selfridge was killed and Mr. Orville Wright injured, and activities

were suspended until the following year, when the Wright Brothers demonstrated their machine, which was accepted by the government. Practically nothing was done in this country until after July, 1910, when the first appropriation of $125,000 was available. A few machines were purchased and a few officers

FIG. 2.



placed under instruction at the aviation school at College Park, Md. In 1911 a small aviation detachment was sent to the Texas border at the Camp of Concentration, and a number of reconnaissances made of the Rio Grande frontier. In 1912 they were used in the manœuvres in Connecticut and also for the observation of artillery fire at Fort Riley, Kan. In 1913 they were again

sent to the concentration camp at Texas City, Texas, and the school detachment subsequently moved to the present establishment at San Diego, Cal., where the training has been continued and detachments sent to the Hawaiian and Philippine Islands. While the number of officers on this duty has been small and the equipment extremely limited, the results obtained by them, I think, are on a par with anything that has been achieved in the military establishments abroad.

Aviation has appealed to the *esprit* of the French nation in a stronger way than to that of any other nation. The French have led in the development of military aviation perhaps to offset the German superiority in dirigibles. Military aviation in the French Army was in 1912 made a separate arm of the service, it having been under the Engineer Corps. It is directly under the War Ministry, and has a general officer at its head. The personnel is composed of officers and men recruited from all arms of the service, and when the new organization is completed the French Army will be in the possession of twenty-seven field detachments, five fortresses, and six coastal detachments, for which 450 machines and twenty-five dirigibles are altogether available. The service is divided into two branches—that of the dirigibles and that of the aëroplanes. The headquarters of the French aëronautical service is in Paris, and the whole of the military aëronautical establishments in France and Northern Africa are contained in three groups, with headquarters, respectively, at Versailles, Rheims, and Lyons. The field detachments are assigned, as a rule, to the headquarters of the various army corps. The Central Supply Depot and aëronautical laboratory is at Chalais Meuden. The personnel of the flying corps at present is 248 officers and 1374 enlisted men.

The military aëronautical troops of Germany are under the command of a general of division, and the service is divided into that of dirigible balloons and that of aëroplanes, each under a separate head at Berlin. The total personnel is 82 officers and 1458 non-commissioned officers and enlisted men. Germany is divided into three grand groups, the first facing towards Russia, the second towards France, Colmar, Metz, Strassburg and the Rhine, the third constituting the entire central hub near Berlin. These troops are divided into four battalions. The first battalion is located near Berlin and at Dresden, the second at Posen, Grau-

denz, and Königsberg, the third at Cologne, Hanover, and Darmstadt, and the fourth at Strassburg, Metz, and Friedberg. Bavaria will have a separate battalion. The present aëronautical project calls for an expenditure of twenty millions by the first of January, 1918.

In Great Britain the military aëronautical establishment consists of the Royal Flying Corps, which comprises the central flying school at Upavon, Salisbury Plain, the naval and military wings, the reserve, together with a separate establishment, the Royal Aircraft Factory, and the government aëronautical laboratory. Control of the military policy is under the Air Committee, which is a sub-committee of the national defence committee. The military wing of the Royal Flying Corps is under the newly-created Department of Military Aëronautics in the War Office, while the naval wing is now managed by the air committee of the Admiralty. So far, no one has been appointed to supreme command of the entire flying corps, as was contemplated in the original scheme, although there is at present some agitation for the establishment of an air department, with a responsible head filling the functions of Minister of Aërial Defence.

There are five aëro squadrons in the military wing, three of them located at South Farnborough, one at Montrose, and one at Nethersdon, and eight stations for the naval wing. There are available for service six dirigibles and one hundred and sixty-one aëroplanes. On the first of January of this year all the dirigibles were transferred from the military to the naval wing of the Royal Flying Corps.

Experience has developed three types of aëroplanes for military purposes: The first, the speed scout, for strategical reconnaissance, a one-seater, with speed up to 85 miles per hour and radius of action of 300 miles and a fast climber, about 700 feet per minute; the second for general reconnaissance purposes with the same radius of action, carrying both pilot and observer, and equipped with radiotelegraphy, slower in speed, about 70 miles per hour, and climbing about 500 feet per minute, and in some cases protected by armor; the third, or fighting craft, armored, and carries in addition to the pilot a rapid-fire gun and ammunition, and so arranged as to have a clear field of view and fire in either direction up to 30 degrees from the line of flight, the speed

to run from 45 to 65 miles per hour, and the machine to climb about 350 feet per minute.

From the foregoing it is easy to infer what the position of the United States is with respect to air power among the nations of the world. We, who in the beginning started the movement, are now at the tail of the procession. We have no dirigibles, but very few trained men, and fewer machines. The manufacturing industry is moribund from the lack of business, and there is no future for it. We have no aërodynamical laboratories in which to study the problems, and no engineering courses, except one, in which to develop our constructors. The government has not stimulated any advance in the design of machines or motors by competition for substantial reward. We have no National League, as in France and Germany, to assist the government by private subscription and by public demand for the development of air power. The interest of our people in aëronautics at large is dead, and has been perhaps so lulled by a sense of false security and the belief that war will not come to such a vast and powerful nation as ours that it will not heed an oft-quoted maxim of the Father of Our Country, "In time of peace prepare for war." In no particular is it more impossible to make up deficiencies after the outbreak of hostilities than in aëronautics. What is to be done? To call to the attention of our people and of our Congress the exact state of affairs to-day. This can well be achieved through the membership of your institution.

Tests of Hardness Effected with a Hand Device. M. F. TURPIN. (*Revue de Metallurgie*, Feb., 1915.)—While not designed for tests yielding the precise results of laboratory apparatus, this simple device is adapted to determining hardness with a satisfactory degree of accuracy for many manufacturing purposes. It consists essentially of a steel ball protruding from the end of a hollow mandrel backed by a cylindrical slug of known hardness on the Brinell scale. Surmounting this slug, a plunger protruding from the opposite end is provided. In use the ball is brought into contact with the piece to be tested, and the free end of the plunger is struck with a hammer. The indentation of the part tested is then compared with that of the standardized slug. The device is 30 mm. in diameter and about 90 mm. long.

RECENT TENDENCIES IN HIGH SCHOOL CHEMISTRY.*

BY

ROBERT H. BRADBURY, Ph.D.,

Head of the Department of Science in the Southern High School, Philadelphia.
Member of the Institute.

I.

LET me first refer, very briefly, to propositions which affect the position of chemistry in the course and the amount of time devoted to it. On account of the great industrial importance of the science and of the high probability of its being of value to the student after his school days are over there has been a widespread demand that chemistry be started earlier in the course,—*e.g.*, in the second year,—and that two years of it be given. Since chemistry is, at present, usually given only in the fourth year, it follows that approximately two-thirds of the one million high-school students of the country leave with no knowledge of chemistry whatever. This seems an unfortunate method of handling a science which is perhaps the most immediately useful subject of the whole curriculum.

Further, we need continuation courses in the science, because they will improve the character of the work. As Dewey has pointed out, in a memorable essay,[1] the excellent results undoubtedly obtained by the study of Latin in high schools are probably due less to the subject matter of the instruction than to its method. Latin runs through the whole four years. The first-year student knows—or can be effectively convinced—that if he neglects his Latin he will be all at sea in it during his second year. The second-year student has the salutary pleasure of using his first-year Latin [2] as an instrument of further achievement. The same statements hold good, with cumulative force, for the third and fourth years.

Let us follow Dewey a little further in setting up an imaginary linguistic curriculum which shall parallel, as closely as possible, our present arrangements for the sciences. It would run somewhat as follows:

---

* Communicated by the Author.

[1] Dewey, "Science as Subject Matter and as Method," *Science*, vol. 31, p. 121 (1910).

[2] Dewey, *loc. cit.*, p. 124.

"The time devoted to each language is about four hours a week for forty weeks. Latin is finished the first year, French the second, German the third, and Spanish the fourth. Similar courses are offered, as electives, in Greek and Italian."

Supposing that this curriculum were offered, in all seriousness, to a representative group of high-school language teachers, would they accept it? Would the herald who voiced the proposed change escape with his life from the fury he had provoked? And would not the teachers be absolutely justified in their enthusiastic rejection of such a proposition? Yet each science offers to the student a far greater task than each language. An earnest student can obtain, without overwork or hardship, a substantial reading knowledge of French in about three months. This is not the sort of knowledge that will fit one to teach a language, but it is the key of the treasure-house of French literature and French science. How much chemistry or physics can one learn in two months? Why are we so much more generous in our allowance of time to the languages than to scientific subjects?

Finally, it is well to point out that the strong movement to establish a generalized science course in the first year has a very definite bearing upon the question we are discussing. Something like a third of the time appropriated to general science would naturally be spent upon the fundamental conceptions of chemistry, and the ideas thus gained would add greatly to the efficiency of the chemical work of the later years.

II.

We turn now to the consideration of those suggestions which affect the method and subject matter of the chemical teaching. Here the chief tendency that calls for comment is a somewhat insistent demand that the "theory" be cut out of the courses, that the work be made more practical, or that the subject be "brought close to the lives of the pupils."

Sir William Hamilton, with his usual penetrating insight, remarks that the "word theory is used in a very loose and improper sense by English writers." In fact, the word is often employed with great freedom by people who become embarrassed when they are asked to explain exactly what they mean by it.

Perhaps the most frequent significance attached to the word

is that of a hypothesis which, on its way to take rank as a fact, has achieved such a measure of probability that it is entitled to be promoted into a kind of special class of near-facts, so to speak. In order to test this meaning let us glance at an example, adapted from Huxley.

A man is sitting quietly by a window. Various sounds, sight-sensations, and perhaps odors affect him, and, because they do not concern him, he gives them only a languid attention. Suddenly he becomes aware of an odor of wood-smoke. This being potentially a matter which does concern him, he is aroused to attend to it, and thinking begins. This thinking takes the form of constructing hypotheses to account for the odor. His neighbor may be lighting a fire, or some one may be burning brush in the street. These being of no special interest, it does not occur to him to verify them; but a third hypothesis, which flits across his imagination, is of such importance that it must be tested at once. He recalls that, a few minutes ago, he withdrew the ashes from his furnace into a wooden box. The ashes were hot, and he is disturbed by the possibility that the wood has been kindled by a glowing ember.

At this stage he disappears down the stairs, with a speed which can be calculated from the laws of falling bodies, and his subsequent proceedings interest us no more. If he finds the cellar in flames, he can reflect with pride that his hypothesis has withstood the test of experience. True hypothesis, the tadpole, has here, in our presence, acquired legs, dropped his tail, and become a fact, but at what stage was the thing a theory? Did it not remain a hypothesis until, in a moment, it was transformed into a fact?

There is, in the evolution of a tadpole, a stage in which, though he has acquired legs, he unwisely holds on to his tail and functions, for a time, as a gawky monster of most displeasing appearance. This would be the biological analogue of a theory, but I am not aware that a hypothesis, in its transformation into a fact, passes through any stage of this kind.

A second sense in which the word "theory" is used is to designate those portions of a science which cannot be directly employed in earning a living. In that case, cutting out the theory would mean the elimination of the entire curriculum, with the possible exception of certain commercial branches. Other meanings there are in plenty, but we cannot delay to deal with them. Let us rather

drop the word altogether, since it seems to have become a mere instrument of intellectual confusion. Hypothesis we know—it means a guess. And fact we know—it means a hypothesis which has proved to be correct. But theory means nothing. It is merely a term which people apply freely to any difficult subject which they do not understand, and of which they cannot grasp the importance.

III.

Looking at the matter from the more positive point of view of the recommendation to make the work more practical, we find, fortunately, that this desire has received concrete expression in several texts, which are worthy of careful study. They begin with a hundred pages of formal chemistry, given in a purely didactic way. This portion is a kind of highly-condensed and abstract grammar of chemical science, and is apparently offered in the hope that the student will be able to apply the principles in the work that follows. The remaining pages are devoted to such subjects as lime, cement, pottery, inks, electric furnaces, pigments, etc. In fact, the books are, to all intents and purposes, elementary chemical technologies.

Here, then, is a definite constructive plan for rendering our work more practical, fully worked out. We have merely to cut down the chemistry to an introductory course, and spend the time upon technology. But, as a matter of fact, is a mass of more or less accurate information about technology likely to prove of greater value to the student than a knowledge of the scientific aspect of the subject? Will he ever need to make his own ink or his own pottery? In the scientific type of text, the student, under calcium carbonate, learns something of the effect of heat upon it, and of the interesting dependence of the process upon the concentration of the carbon dioxide in contact with the solid. Here we have, instead, a two-page description of the manufacture of lime in a rotary kiln. Is not the hypothetical practical character of this kind of knowledge a pure illusion? Of course, the fact that lime is not really made in rotary kilns is an unfortunate accident, but, even if it were, in what way could the student make any actual use of his knowledge of the process?

This leads to the remark that the technology in the texts which feature that subject is apt to be inaccurate. It is most

difficult for a text-book writer to be sure of his technology. The technological journals do not speak with the authority of the journals devoted to pure science. They contain numerous articles which are written for advertising purposes, and which must be read with great caution. The real methods by which results are obtained are often carefully kept secret. To quote from a review: "The technology of the average elementary text is a species of museum, in which processes discarded elsewhere are preserved forever, like insects in amber."

But even if the author of a book of this type should succeed in making the technology accurate, it would not long remain so, for technology changes with astonishing speed. I have known chemical manufacturers to object to the permanency of concrete buildings, because their solidity introduced difficulties when it became necessary to "scrap" the plant to keep pace with progress. We should firmly grasp the fact that, in changing from chemistry for technology, we are deserting knowledge of proved permanent worth, to deal in information whose chief characteristic is the evanescence of its value. The technology we teach now will merely mislead our students ten years hence, unless they have been able to keep up with the progress of the subject.

There is another important point which is commonly lost sight of by those who insist that we should confine our teaching to the applications. Technology is simply applied science. "There can be no applied science without science to apply." To teach nothing but the applications would sterilize chemistry and destroy the possibility of progress. The applications themselves would at once stagnate. The disinterested research of to-day is to-morrow the basis of an industrial process, and is directing the production of the luxury or the necessity of thousands. Pure science is the most intensely practical of all human activities. Those who sneer at it are ignorant of history. In about a century it has transformed the conditions of human existence, and its work is hardly begun. It is the only occupation worthy of a man who desires to benefit the world as much as possible by his residence in it. Science is by far the greatest of all the forces working toward the material and mental uplift of the people. A child who gives up four years to a higher education has a right to as much of it as we can give in the time—all too short—at our disposal. And I may digress for a moment to remark that it seems to me

little short of robbery to waste his course with chicken-feed of the fruit-spot, ink-spot, grease-spot, garbage-can type—a proceeding which leaves him, at the end, ignorant of chemistry but the fortunate possessor of a few bits of household information, which he could obtain from any intelligent woman in five minutes.

If, then, technology is really no more useful to the student than chemistry; if the technology of those elementary texts which specialize in it is often quite hopelessly inaccurate, and if, even when accurate, it does not "keep," I hold that it would be a bad blunder to eliminate our chemistry and to substitute for it a scrappy mass of information about technical processes. Such a course would be perfectly incoherent. It would have no beginning, no logical development, and no end, and would lead nowhere.

Yet technology has an important place in the course, but its place is subordinate. The wise teacher will vitalize his work by constant brief references to the applications. He will keep the tremendous industrial importance of chemistry continually before his students, but he will do this without discarding the main object. The proposition to omit chemistry from the high-school curriculum, and to substitute elementary technology for it, is merely another instance of that muddle-headed worship of the word "practical" which is the bane of Anglo-Saxon thinking.

IV.

Glancing now at the third slogan, "Bring the subject closer to the lives of the pupils," we must admit that this rather vague expression has a content of fact that is well worth noting. The essence of good teaching is to proceed from the familiar to the unfamiliar, from the concrete to the abstract. Chemical facts are all about us. The beginner has an abundant supply of them stored up from his daily experience, though he does not recognize their chemical character until his attention is directed to the point. It is a matter of first-rate importance to utilize this information, which he already possesses, as a foundation for the structure we are trying to build. This leads to a copious use, especially at the outset, of materials drawn from the daily life of the students. Each subject should be started, if possible, with something familiar and concrete to the beginner.

I admit freely the difficulty of this. Alexander Smith says:

"We cannot possibly confine ourselves to common materials in attempting to teach the science. We simply cannot summon it forth from a mass of information about cooking, agriculture, rusting, and photography by any legerdemain." It is also true that the strength of the appeal depends upon the character of the experience of the student. Professor Whitsit remarks that most of his beginners live in small flats, where everything is operated by push-buttons, and where there is an utter lack of chemical data. Physics is more fortunate than chemistry, so far as this question is concerned.

Admitting these difficulties, the fact remains that the available experience of the beginner is a most important element in the work, and that the teacher's success will be nearly proportional to his ability to appeal to it—to make his teaching homely, rather than didactic and academic. And when there is nothing to appeal to, we have to create new experience with the mineral collection, the lecture experiments, and, best of all, in the laboratory.

Take the subject of the atomic weights, for instance. They are the very foundation of our science. It is the chief peculiarity of chemistry that it achieves simplicity by operating with different weights of the elements, instead of basing its reasoning upon unit weight, as do the other sciences. There is no subject more important than the atomic weights, and none more difficult, if we do nothing but talk about them. But there are at least four atomic weights which can be determined by the beginner in about sixty minutes with the simplest apparatus and with an accuracy of at least one unit. After the student has done this work his difficulty in handling the atomic weights disappears. They have become concrete to him, and he uses them in his calculations with perfect appreciation of their significance.

V.

It is surprising to find that the fundamental axiom of good teaching—from the familiar to the unfamiliar, from the concrete to the abstract—is violated at all points by the order of topics which is still largely in use in presenting chemistry to the beginner. The current order seems, indeed, to lay stress on starting with the unfamiliar, since it begins with such wholly abstract subjects as matter, energy, molecules, and atoms, and since unfamiliar sub-

stances are hurled at the student by the dozen at the very outset. It will be obvious that the plan of giving abstract general concepts to the beginner at the start, when they are entirely unintelligible, with the hope of using them later, is foredoomed to failure. Such concepts should be introduced naturally in the course of the work, as the need for them arises, and when the student has the experience which renders them intelligible. And the use of substances strange to the student, as examples of such processes as solution and crystallization, should be avoided. These things can be much better explained by instancing sugar and salt than by bewildering the beginner by references to copper sulphate, potassium chlorate, and carbon disulphide. We are prone to forget that the chemical names, which are so simple and full of meaning to the teacher, are, at the outset, mere bizarre jargon to the beginner. The student must, of course, be made acquainted with these substances, and with many others, but they should not be introduced until the proper stage has been reached for their full discussion. To attempt to explain a new concept, like solution, by referring to the behavior of a totally unfamiliar substance, whose very name the beginner cannot pronounce, is to destroy all chance of comprehension. The more homely the instance the better. The student who has watched the behavior of the sugar in a glass of lemonade has started on the path which leads to the peak whence he can view the territory opened up by Raoult, Arrhenius, and van 't Hoff, in all its spaciousness.

Another bad defect in the usual order of topics is that the earlier part of the work is concerned almost entirely with colorless invisible gases. The only gases the beginner knows are air and illuminating gas, both of which are complex mixtures. Much later in his work, he is profoundly surprised and interested when told that anything so unsubstantial as air can be converted into a liquid. Of a gas as a special form of a single pure substance he has no conception whatever.

At this time the beginner is grappling with ideas which are new and difficult to him, and which are indispensable to his mastery of the subject. The foundation offered to him for the struggle is almost ideally bad. The experimental evidence consists chiefly in changes in the level of liquids in certain graduated glass tubes which the teacher, very wisely, will not allow him to touch. The experiments are impossible in the laboratory, and in the class-

room the student cannot read the graduations, and has to take the results on faith.

Take the electrolysis of water. The experiment is dramatic and it always interests the students, but interest, though a necessary condition of success, is not sufficient to it. Question the class a week later. How many have clearly perceived the fundamental fact that every bubble of gas means that an equivalent amount of water has disappeared? This point is in no way brought out in the experiment. Many students imagine, on the contrary, that additional water is formed because of the rise of the level of the liquid in the funnel-tube. How can we explain to them at this stage, or even later, the function of the sulphuric acid? How shall we prove to them that the gases really come from the water, the acid remaining unchanged? And if they are willing to take all this on faith, the only addition to their intellectual equipment is the proposition that when an indefinite and unperceived mass of water disappears two parts of hydrogen and one part of oxygen make their appearance. From this they will at once draw two conclusions:

First.—That water contains twice as much hydrogen as oxygen, whether by volume or by weight is all one, so far as they are concerned, for they do not distinguish clearly at this stage.

Second.—*Therefore* the formula of water is H_2O. Thus they lay the foundation for a comprehensive misunderstanding of the meaning of chemical formulæ, from which it is very difficult to free them later. Ohmann is absolutely right in his contention that this important experiment should be deferred and taken up much later, in connection with sulphuric acid, ionization, and electrolysis.

As a contrast to this, consider the heating, by the student himself, of a gram or so of fine copper wire with sulphur in a closed porcelain crucible. The copper and sulphur have unmistakably vanished. The new gray-black product is visible, tangible, and *weighable,* and the increase in weight happens, fortunately, to be almost exactly one-fourth of the weight of the copper taken. We have, in other words, a rock foundation for the beginner's feet, as compared with a quicksand. A rational order of topics would start with familiar solids like copper, lead, tin, and sulphur. It would settle the all-important question of *combination by weight* before attempting to elucidate the behavior of gaseous molecules.

and it would settle this question by experiments which the student could carry out for himself.

It will be seen that the question whether the work should be quantitative or qualitative is one which carries with it its own answer. The laboratory work is not to be regarded as a thing apart. The course has often been compared to a pattern woven of many threads, and most of these threads can only originate in the laboratory, the great object of which is to furnish the sense-experience with which alone the weaving can be accomplished. To make the work all quantitative leads to narrowness, and to serious loss of time. On the other hand, to omit all quantitative experimentation deprives the student of all basis for his reasoning, and introduces almost insuperable difficulties in the way of teaching the subject. As a tentative suggestion it may be remarked that a laboratory course in which one-third of the experiments are quantitative lends itself readily to definite interrelation with the class-room work, and develops good manipulative habits in the students.

The dominant motive in a rational arrangement of the work is the effort to develop each topic out of some concrete familiar instance, so that the matter will be significant to the student from the start. Success depends mainly upon constant attention to this principle. The difficulties in the way have been briefly referred to. Daily life often leaves us in the lurch, but, when this happens, a mineral, or a well-executed laboratory experiment, is an excellent starting-point.

Almost no weight can be attached to systematic chemical classification in the arrangement of elementary work. To group gold and silver with sodium, manganese with chlorine, and chromium with sulphur, hoping that the beginner may reap some benefit later, is a waste of time. Even to the chemist such groupings are not wholly satisfactory, and to the beginner they are altogether artificial and unreasonable. The only families which should receive detailed consideration are those in which the analogies are quite unmistakable, especially the halogens and the alkali metals. The most important task in the reorganization of high-school chemistry is to rid the work of the Procrustean influence of chemical classification, which, after all, is unintelligible without a considerable knowledge of the rare elements. At the end of his course the beginner will not know the names of elements, a rather

detailed knowledge of which is essential to the understanding of the classification according to which his work has been arranged. We have come from the universities and taught our students as we were taught and the plan does not work well, for the standpoint of the students and the objects of the work are different.

VI.

In a recent examination for candidates for teacherships in high schools the question was asked whether the *simple* formula H_2O applies to ice, to liquid water, or to steam, with a request for a statement of the reasons for the answer. The effect of this innocent query upon the candidates—university and technical school graduates mainly—was appalling, and the examiner might well have been charged with making the questions too difficult. Yet it is plain that any one who is unable to reply intelligently to this question is in a condition of almost complete ignorance with regard to the meaning of the formula and the foundations upon which it rests.

This is a striking instance of a remarkable peculiarity of chemical instruction, not only in high schools, but in higher institutions. I refer to the stress laid upon subject matter and the neglect of method. Everywhere the object of the work seems to be to give the student a highly-condensed account of the results of the science, without much reference to the method by which its results have been obtained. Whether this is wise or not is a question which deserves much more careful consideration than it has hitherto received. I should be the last to deny the usefulness of chemical information. Yet it is difficult to avoid the conclusion that to most people some conception of scientific method is far more important. The possession of a large amount of information does not alone make a man educated. Education consists rather in the attitude of mind which enables a man to differentiate information from misinformation, and to understand what evidence he ought to require, before giving his assent to a proposition which may at any time assume first-rate importance as a guide to conduct.

This attitude is almost as far removed from mere blank Pyrrhonism as it is from unreasoning credulity. Its chief constituents are a willingness to examine the evidence for any state-

ment, a rooted objection to accepting any statement without evidence, and, finally, the ability to estimate correctly the value of the evidence. It is almost identical with what is commonly called "good judgment," which is a very different thing from technical knowledge. The man who has judgment, but who lacks the specific knowledge necessary to solve a problem which confronts him, can usually make up his deficiency either from books or from other men whose business it is to possess the knowledge which he needs, but the man of wide knowledge, who lacks judgment, will, in spite of his learning, and often because of it, flounder in one disastrous error after another his whole life long.

All of us have known men who, with little technical knowledge, have yet achieved success. The study of such a man will invariably show that, along with aggressive energy, he possesses, in unusual degree, the power to appraise quantitatively the considerations for and against a given course of action. His acquaintances usually recognize the presence of this ability by consulting him about their own problems. And the term "foresight," by which they often designate his special faculty, serves notice upon us that we are dealing with that familiar effort to predict the future from the past which constitutes the pretence of the charlatan, the main business of science, and the chief element of success in common life.

The study of chemistry purely as subject matter is not the best method of acquiring knowledge, and it does absolutely nothing to cultivate the judgment. It may perhaps be objected that such qualities as energy and judgment are innate, but this is merely begging the question. Those who have observed the great development of both energy and foresight which often occurs in a man who is suddenly subjected to new and increased responsibilities will hardly be disposed to assent to the hypothesis of their innateness. How do we know what qualities are innate and what can be cultivated? Perhaps no mental attribute is altogether innate. I admit that the power in question—to marshal the data in an orderly way, to state the problem with precision, and to construct hypotheses which are usually verified by the sequence of events—seems like part of the very fibre of a man's personality, but this is merely because he is using it so continuously that it becomes part of our conception of him. On the other hand, his ability, say, to analyze an iron ore with exactness is only occasion-

ally brought into play, and it impresses us, therefore, as something extrinsic and acquired.

It is interesting, also, to speculate upon the biological aspect of the question. Biologists seem, with reason, to be agreed upon the proposition that acquired characters are not inherited. Assuming that we may invert this thesis, the exceptionally foolish and worthless sons, who often appear in the families of men of commanding ability in financial and industrial directions, lend no support whatever to the assumption that qualities like energy and foresight are innate. And that it is worth while to consider these qualities, in our scheme of science teaching, is indicated by the fact that the men at the helm of all great enterprises—while they may, and often do, possess astounding technical knowledge—are hired chiefly for their foresight, and for their ability to get things done.

I trust that no one will imagine that I am trying to depreciate scientific knowledge. In an industrial civilization, continually growing more complex, the importance of special knowledge is sure to increase, and this is particularly true of chemistry and physics. But it seems to me that to give some attention to scientific method, along with the subject matter, would give our courses coherence and vitality and would greatly increase their interest and value.

Historical Note on Electrolytic Iron. M. L. GUILLET. (*Revue de Metallurgie*, Feb., 1915.)—The commercial manufacture of iron by electrolysis is a problem studied for a very long time, but it is only within recent months that it has reached the field of practical application. About 1860, at St. Petersburg, Klein obtained plates of electrolytic iron for printing bank notes. Klein's bath consisted of a solution containing iron sulphate, 5 per cent., and magnesium sulphate, 5 per cent. This bath worked with feeble current density, 0.1 to 0.3 ampère per decimetre square. It was maintained neutral by the addition of magnesium carbonate. In 1867 Feuquières exhibited in Paris some galvanic deposits of iron, but the process employed was never divulged. At Aix-la-Chapelle, in 1881, Classen devised a method of preparing iron electrolytically by employing a solution of the double oxalate of iron and ammonia with an insoluble platinum electrode. This process has remained an exclusively analytic one. In 1900 the house of Merck, in Germany, secured a patent (German patent No. 126,839) based on the electrolysis of pure ferrous chloride in highly-concentrated solution. A temperature of 70° is requisite, and a current density of 3 or 4 ampères per decimetre square. In America, in 1904, Burgess and Hambuechen succeeded in preparing

considerable quantities of iron by electrolysis of a bath based on sulphate of iron and ammonia, the temperature being kept at 30° and the current density at 0.2 to 0.3 ampère per decimetre square. These processes had for their main object the refining of iron, but were not applied commercially. At about the same period Professor Foerster, of Dresden, in collaboration with his students, made several researches on electrolytic iron. These studies are outlined in a publication entitled *Electrochemical Properties of Iron* (edited by Knapp, at Halle). Professor Foerster obtained the best deposits with a solution of iron sulphate maintained slightly acid at a temperature of 95°, the current density being about 2 ampères per decimetre square. In 1897 Cowper-Cowles obtained a patent for the use of a solution of sulphocresylate of iron of 20 per cent. and attempted to produce directly seamless tubes by employing a rotating cylindrical cathode. This process, analogous to the Elmore process for copper tubes, has remained in the laboratory stage and has not given practical results. In Germany, in 1909, Professor Fischer, of Berlin, and the works of Langbein Pfanhauser, at Leipzig, obtained a number of patents relating to the electrolysis of iron. German patent No. 212,994 prescribes the use of very concentrated solutions of iron chloride and calcium chloride working at a temperature of 110° and a current density of 20 ampères per decimetre square. Although this process excited widespread interest, it is not known whether its commercial application has been realized. In any event, it is not intended for the direct production of thin plates; it would appear that the process is applied to the production of more or less imperfect rough plates which are subsequently rolled to size. The process is, therefore, in great part, mechanical. Beginning in 1910, a company, under the name "Le Fer," at Grenoble, secured a number of patents for the electrolysis of iron. These patents are based upon the use of a rotating cathode in a neutral solution of ferrous salts maintained neutral by circulation of the liquid about the iron surface. Moreover, the bath receives periodic additions of a depolarizer, such as oxide of iron, with the object of eliminating—at least in part—the hydrogen which collects on the cathode and injures the deposit when it accumulates in too great volume. With this arrangement it is possible to employ high current density (1000 ampères per square metre), and an excellent quality of iron is produced. The patents of the "Le Fer" company cover the production of *very pure iron*, comparable with the high-quality Swedish irons, either *in the form of tubes or plates obtained directly by electrolysis in the finished state*. This process has passed the laboratory stage and is actually commercial. An option on a license to manufacture these tubes and plates has been secured by the works of Bouchayer and Viallet. An exhibit of commercial tubes has been displayed at the Exposition of Lyons by the latter firm, which is completing the erection of a large mill for the manufacture of this product.

An illustrated account follows, giving at length data on the finished product and technical detail of its manufacture.

LOSS OF WEIGHT OF MUSK IN A CURRENT OF DRY AIR.*

BY

CHARLES B. BAZZONI, A.M., Ph.D.

MANY attempts have been made to determine the smallest mass of an odorous substance that can excite the sense of smell. These investigations have been suggested by the assumption that the sensation of smell is stimulated by the direct impact of the particles of matter on the olfactory tract and have had for their ultimate purpose the formulation of a satisfactory theory of smell causation. We may say, in passing, that the questions as to how smell sensations are produced and as to how different odors are related or differentiated are still open. The number of facts known is not sufficient to justify the formulation of a theory. It is interesting to refer to the well-known work of Fischer and Penzoldt,[1] who found that 1 part of musk in 10,000,000 of air and 1 part of mercaptan in 50,000,000,000 of air could be detected, and to that of Passy,[2] who detected 0.000005 gramme of musk in a litre of air, 0.005 mg. of camphor, and 0.00000004 mg. of mercaptan.

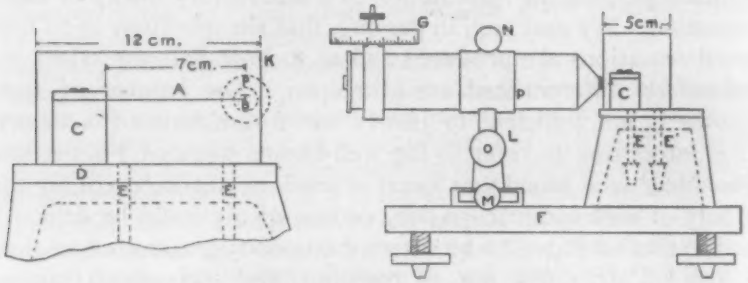
It seems fair to assume that the primary sensation is due to particles of the material carried by the air into the nose, and to consider certain, therefore, that all odorous materials must constantly lose in weight. The results of Passy seem to show that the loss even of strongly odorous substances need not be very great and might consequently be hard to detect and harder still to measure. The attempt has been made several times to measure this loss, using musk. As a result of these attempts it has been stated not infrequently that this substance gives off its odor during years without losing at all in weight, but any one familiar with the hygroscopic character of musk granules will realize at once that a small loss might be completely masked unless extraordinary precautions were taken. In the investigation here recorded the loss

* Communicated by Dr. Joseph S. Hepburn.

[1] *Sitzungsberichte der physikalisch-medizinischen Societät zu Erlangen*, 1885–1886, xviii, 7.

[2] *Comptes rendus de la Société de Biologie*, 1892, xliv (ix Serie, iv), 84.

of musk has been detected and measured with some accuracy. It must be remembered, however, in dealing with musk granules, that this material is composed of a complex mixture of organic compounds—blood, hair, and sebaceous substances—in themselves complex and subject to evaporation, the products of which may or may not be odorous. Further, since the "odor" or the small odor-producing particles may not constitute all of the loss of weight, or, indeed, excepting by presumption, any of it, the results of these experiments can not be applied directly in the formulation of any theory of smell causation. A proper physical method for the differentiation and classification of smells must apparently involve a study of the physical character of the molecules or



FLEXURE MICRO-BALANCE NO. 1. C. B. BAZZONI.

A. Quartz fibre.
B. Glass pan.
P. Micrometer microscope.
E. *E'*. Inlet and efflux tubes.
D. Plate glass base.
K. Glass case.
C. Brass pillar.
M, *L*, *N*. Lateral vertical and longitudinal microscope adjustments.
G. Micrometer head.
F. Cast-iron base.

molecular aggregates suspended in odorous vapors. This necessitates an investigation of a high order of difficulty which has been undertaken in this laboratory, but which has, so far, produced no very significant results. It is to be observed that loss-of-weight experiments made in this connection have their main significance as studies of solid evaporation.

In the investigation here recorded a special form of micro-balance was devised to meet the particular requirements. A quartz fibre with a very light pan of thin glass cemented on the end of it was rigidly supported in a horizontal position inside a small glass case. The musk was placed on the pan and the changes in flexure of the beam, which, of course, accompanied the changes in weight, were measured by means of a reading microscope placed

outside the case. It is evident that when small loads (0.5 mg. to 1 mg.) are under investigation a very high sensibility may be obtained by selecting a fibre sufficiently thin and a microscope sufficiently powerful. Practically the limit is set by disturbances due to vibrations from external sources and by drift phenomena due to viscosity or to fatigue and to temperature changes in the fibre. These difficulties are, of course, tremendously magnified by the use of very thin fibres or of powerful microscopes. The drift phenomena have been studied separately and have yielded results of some interest, now in course of preparation for publication under the title of "Elastic Hysteresis and Fatigue in Glass and Quartz Fibres." The micro-balance here described was easily usable on an ordinary heavy table, and, when provided with fibres of approximately 0.13 mm. diameter, had a sensibility of 0.00000007 gr. per head division. This means that a loss of weight of 0.00007 mg. in the load on the pan caused a rise of the pan measurable by a rotation of one head division of the micrometer screw on the microscope. A sensibility of 0.00001 mg. was reached by using a thinner fibre. It will be remembered that the sensibility of the best analytic beam balances does not exceed 0.05 mg. per scale division. The details of construction are apparent from the diagram. The base F was of massive cast iron, to cut down disturbing vibrations. The glass base plate D was perforated, and into the holes tubes were cemented, terminating in ground-glass cones. The case could be evacuated or filled with any desired gas, or a current of gas could be maintained through it. The stiffness of each beam was measured by determining the flexure under known loads. When the constant thus determined is multiplied by the shift of the fibre measured in head divisions we have the change in weight of the specimen.

This balance is obviously well adapted to the solution of this particular problem, in which a small quantity of material undergoing relatively small and slow changes in weight must be kept under observation for a long period of time. Although no great skill is required to manipulate the instrument, it must be remembered that any shifting of the load along the axis of the beam will, unless corrected for, produce a marked error in the results. With one particular beam a shifting of a one-milligramme weight through 1 mm. caused a change in the flexure of 0.061 mm., indicating apparently a change in weight of 0.14 mg. Further, in the

interpretation of the results grave errors will occur unless allowance is made for both fatigue and hysteresis, which differ for different beams and with the temperature of any given beam, and which must be determined by experiment for each beam. This balance has, subsequent to the date of this investigation, been modified in many details in order to make it more suitable to work on solid evaporation. For general micro-gravimetric work the triangular beam quartz micro-balance of Steele and Grant,[3] though more difficult to manipulate, is nevertheless to be recommended.

A number of series of observations on loss of weight of musk were run with the balance above described during the years 1912 and 1913. The figures for a single series are given below. In this determination dried air was aspirated through the case constantly. Preliminary series showed that with the tubes open to the outside air the changes due to the alternate absorption and evaporation of water completely masked the changes in weight due to the evaporation of the musk itself. The beam merely rose and fell irregularly, with a period ordinarily of several days, depending on the humidity. (Refer to the results for Experiment A.) When the case was filled with any gas and then closed the beam acted as if the load neither lost nor gained. The phenomena of solid evaporation are, naturally, closely analogous to those of liquid evaporation. In a closed space a saturation density is reached more or less rapidly, and beyond this point evaporation, reaching a steady state, apparently ceases. With a modified form of this apparatus determinations of the saturation densities of the vapors of certain solids as functions of temperature were made subsequently and are now being prepared for publication. It is apparent that a steady loss of weight due to evaporation, odorous or otherwise, can be determined only when the material is in a current of dried gas.

RECORD.

Preliminary.—The beam under a load of 1 mg. showed as a mean of ten determinations a flexure of 4.33 mm. per mg. Each head division of the micrometer was equivalent to 0.00003 mm., wherefore one head division change was equivalent to a weight change of 0.00007 mg.

[3] *Proceedings of Royal Society of London*, Series A, 1909, lxxxii, 580.

Experiment A.

1.0436 mg. musk on pan. Musk not dried. Temperature, 18° to 20°C. Tubes open to the air.

1912. October 24, 12 M.	0	
4 P.M.	150	h. d. down.
25, 4 P.M.	140	h. d. down.
26, 2 P.M.	273	h. d. up.
5 P.M.	20	h. d. up.
27, 9.30 A.M.	93	h. d. up.
28, 9 A.M.	290	h. d. down.
2 P.M.	35	h. d. down.
(Current of dry air started.)		
6 P.M.	1250	h. d. up.
29, 9.30 A.M.	450	h. d. up.

This specimen continued to lose weight at a lessening rate for several days. It was then accidentally knocked off the pan and a new series had to be started. Observe here the disturbing action of absorbed moisture.

Experiment B.

1.32245 mg. of musk, previously dried in an oil oven, on the pan. Current of dried air flowing steadily and slowly through the case.

	Hours		H. d. change	Loss in weight
1912. November	1, 12 M.		0	
	2, 9 A.M.	23	66 up	.00462
	3, 10 A.M.	25	68	.00476
	5, 9 A.M.	47	138	.00966
	6, 9 A.M.	24	60	.00420
	7, 9 A.M.	24	62	.00434
	9, 9 A.M.	48	126	.00882
	10, 10 A.M.	25	54	.00378
	12, 9 A.M.	47	110	.00770
	13, 9 A.M.	24	48	.00336
	14, 10 A.M.	25	51	.00357
	15, 9 A.M.	23	48	.00336
	16, 11 A.M.	26	47	.00329
	18, 9 A.M.	46	88	.00616
	20, 9 A.M.	48	84	.00588
	24, 10 A.M.	97	142	.00994
	25, 9 A.M.	23	32	.00224

		Hours	H. d. change	Loss in weight
	December 3,	10 A.M. 193	207	.01449
	8,	9 A.M. 119	106	.00742
	10,	9 A.M. 48	40	.00280
	15,	9 A.M. 120	90	.00630
1913.	January 6,	9 A.M. 628	397	.02779
	7,	9 A.M. 24	15	.00150
	8,	9 A.M. 24	13	.00091
	9,	9 A.M. 24	13	.00091
	15,	9 A.M. 144	72	.00504
	25,	9 A.M. 240	97	.00679
	February 10,	9 A.M. 348	126	.00882
	14,	9 A.M. 96	27	.00189
	25,	9 A.M. 264	58	.00406
	March 7,	9 A.M. 264	55	.00385
	10,	9 A.M. 72	14	.00088
	20,	9 A.M. 240	43	.00301
	April 6,	9 A.M. 408	42	.00294
	15,	9 A.M. 216	17	.00119
	25,	9 A.M. 240	18	.00126
	26,	9 A.M. 24	2	.00014
	May 8,	9 A.M. 288	5	.00035
	15,	9 A.M. 168	3 down	
	20,	9 A.M. 120	4 up	.00028
	24,	9 A.M. 96	2 down	

Total loss of weight, 0.18941 mg.
Per cent. of total weight comprised in loss, 14 per cent.

Rate of loss, in mg., per day for each month:

November	December	January	February	March	April	May
.00318	.00135	.00087	.00035	.00025	.00017	.00002

Per cent. of total loss in each month:

November	December	January	February	March	Apri	May
53+	22+	14+	5+	4+	2+	0.3+

On this date the series was discontinued, and the musk, after being removed from the case, was subjected to microscopic examination. The surface seemed somewhat altered in appearance, being more dense or glazed than on a fresh granule, but the general form and apparent size were unchanged, so far as could be judged. No odor was perceptible even after crushing and exposing to the air for forty-eight hours. Moistening did not restore the odor. The granules, when introduced into the case at the beginning of the experiment, had a very distinct odor. Before introduction into the balance case these granules had been heated

in an oil oven at 120° C. for five hours in order to expel all moisture.

One important point has not been mentioned. The air drawn through the case was dried chemically[4] by aspiration through $CaCl_2$, H_2SO_4, P_2O_5 and KOH in large U tubes in the order named. The air current was maintained by a water aspirator and had a low velocity. It is not impossible that the air passing through the case contained chemical vapors which may have acted on the musk. This is a possible source of error, but on account of the low velocity of the air and of the order in which the drying agents were placed it does not seem a real one. Errors due to elastic fatigue were not corrected for in this series. These fatigue effects, however, would always be evidenced as an apparent gain in weight. It should be observed that a stationary beam means a balance of loss in weight against the droop due to viscosity, but this droop becomes negligibly slow after 12 or 15 days, as is demonstrated in the paper on "Elastic Hysteresis," previously referred to. The room temperature ranged between 18° and 20° C. throughout the observation periods, so that temperature effects ought not to have been noticeable.

These results seem to justify the following conclusions: Musk does lose weight when exposed in a current of dried air. This loss is not due to the evaporation of water. After the loss of weight has ceased the musk is no longer odorous. The odor is not restored by exposure to moist air.

In concluding it is desired to point out that the loss of weight here measured is recognized to be due merely to the loss by evaporation of the volatile constituents of this particular specimen of musk. Further, the per cent. of volatile constituents must almost certainly be different in different samples, since musk as it occurs commercially is a complex variable mixture. Also, since the rate of loss must be dependent largely on the relative distribution of the volatile and non-volatile portions of the granule, this rate must be expected to be variable for different granules and irregularly variable during evaporation from any one granule.

Randal Morgan Laboratory,
University of Pennsylvania.

[4] Glass beads wet with sulphuric acid were used. The other reagents were used in solid form.

Stream Gauging and Hydraulic Science. (*Water-supply Paper 375-C*, United States Geological Survey.)—In the great advance which applied science has made in the last generation a prominent member of the vanguard has been the stream gauger—the measurer of the volume of flowing water. His rapid progress is even more notable when it is considered that his work was born hardly a generation ago. In 1889, the United States Geological Survey began investigation of the water resources of the country, and so little work of that kind had previously been done that the beginners felt that they were entering an entirely new field of research. Owing very largely to contributions of the engineers of the United States Geological Survey, stream gauging has developed empirically and scientifically until it comprises a field of classified knowledge which well entitles it to a dignified place among the sciences. As a science it is a subclassification of that longer recognized and more inclusive science of hydraulics. Knowledge of it is required in practically all branches of engineering, and it is being taught as a regular course in many of the leading scientific schools. The relation of stream gauging to the science of hydraulics, stream gauging as a science, and the probable future developments are discussed briefly in a report by C. H. Pierce and R. W. Davenport, recently issued by the Geological Survey as Water-supply Paper 375-C.

In regard to future developments the authors say: "It seems probable also that in the future the results of accurate stream gauging will be utilized in connection with problems in meteorology and physiography. Although the determination of better coefficients for use in the accepted hydraulic formulas and the deduction of new laws not heretofore expressed may be confidently expected, it should also be remembered that the results of stream gauging have already been applied to the measurement of rainfall on a large scale and to problems involving no less complicated features than the determination of effects of deforestation on the navigability of interstate streams."

A New Crystalline Variety of Silver. T. C. CHOUDHRI. (*The Journal of the American Chemical Society*, vol xxxvii, No. 9, September, 1915.)—Spongy silver, prepared by igniting pure silver tartrate, was treated at the ordinary temperature with strong nitric acid (sp. gr. 1.42) from which lower oxides of nitrogen had been removed by boiling with carbamide. At first some action took place with the formation of silver nitrate and nitrous acid, but after a time the solution of silver stopped, and on allowing the mixture to stand with occasional shaking for about two weeks, the remaining silver was converted into long, needle-shaped crystals easily visible to the naked eye; slender needles which when first formed appear floating on the acid liquid. This is considered to be a new variety of crystalline silver belonging to the cubical system.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

STANDARDS FOR ELECTRIC SERVICE.

[ABSTRACT.]

ELECTRIC light and power companies are now subject to regulation by State commissions in more than half of the States of the Union, and by municipal ordinance in a number of cities in States not having commission regulation. The supplying of electric service to the public is largely a monopoly, and regulation on behalf of the public is generally considered necessary and economically advantageous.

Owing to the very rapid development and constant changes in methods and apparatus, it has heretofore been difficult to fix standards for electric service for general adoption. Developments are, of course, still going on, but the methods of electrical distribution and measurement in common use, and the criteria of good service generally accepted, have become so largely standardized by practice that it is now possible to formulate standards of service that will be generally acceptable.

The popular movement for the regulation of public utility corporations has spread rapidly since 1907, and at present there are corporation commissions, public service commissions, or railroad commissions in every State save two. In the States of Arizona, Connecticut, Illinois, Indiana, Missouri, Montana, New York, New Jersey, New Hampshire, Nevada, Pennsylvania, Oregon, Washington, West Virginia, and Wisconsin and the District of Columbia orders and rules for the regulation of electrical corporations have been issued by the commissions. Similar rules are under consideration in several other States, while a few commissions have so far issued only certain recommendations. Circular No. 49 of the Bureau of Standards discusses the most important factors constituting and promoting safe and adequate electric service, the circular being based on a careful study of the experience of operating companies and regulating bodies, both State and municipal. The circular contains, first, rules and recom-

* Communicated by the Director.

mendations for the regulation of electric service companies by State commissions; second, three different ordinances suitable for adoption by towns and cities in States not having regulation by commissions; third, specifications for the approval of types of electricity meters by commissions; and, fourth, all orders, rules, and regulations so far adopted by commissions for electric service.

The rules suggested as suitable for the consideration of State public service commissions are the result of conferences and correspondence with nearly all of the commissions, and careful study and comparison of existing orders and rules.

The suggested regulatory ordinances for electric service in cities are based on a very careful study of the subject and conferences with many operating companies and others qualified to express opinions. Ordinances regulating electric service are so far in force in a very few towns and cities, and in most instances are limited in application to meter inspections and tests upon customers' complaints. Three different ordinances, varying in scope and length, so as to make them useful to municipalities of all types, from small towns to the largest cities, are proposed and discussed. It is believed these suggested ordinances will be of considerable interest and value to municipal authorities in cities and towns situated in States not having commission regulations of electric utilities.

A brief description of the electrical testing equipment provided by each State commission for the calibration and standardization of "working test standards" used by central stations in their meter work, and for making tests on customers' meters upon complaint to commissions, is of interest to operating companies, and particularly to commissions considering the equipment of similar laboratories.

In appendixes are reprinted certain sections of State public service commission laws, relating particularly to the regulations of electric service as to adequacy and safety, and, in addition, tables and summaries on various phases of voltage regulation, meter testing, and general central station statistics.

The Bureau asks for criticisms and suggestions from operating companies, commissions, State and city inspectors, committees of associations and engineering societies, and all others interested in the establishment of proper standards for electric service.

DIFFERENCE IN WEIGHT BETWEEN RAW AND CLEAN WOOLS.

By Walter S. Lewis.

This investigation was made (1) to obtain some definite knowledge as to the shrinkage of some of the foreign raw wools imported into this country, (2) to ascertain the shrinkage variation in two samplings of the same fleece, and (3) the difference in shrinkage between two fleeces of the same breed of sheep which were grown in the same section of country. The term "shrinkage" as used here means the total loss, by weight, of all grease and dirt. This elimination of grease and dirt was accomplished by first scouring in a warm solution of pure olive-oil soap and then extracting the remnant grease with ether; the loss is therefore the shrinkage, and pure wool fibre remains. In commercially scoured raw wool there remains from 1 to 3 per cent. of the wool grease, therefore to arrive at the shrinkage which would obtain in ordinary mill practice from 1 to 3 per cent. must be subtracted from the shrinkage results shown in the tables of this paper.

Conclusions.—(1) Forty-nine fleeces were carefully sampled and thoroughly cleansed of all grease and dirt, the results showing shrinkages from 19.5 to 54 per cent., according to the breed of sheep.

(2) In the South Australian wools the greatest shrinkage difference between two determinations upon samples drawn in the same manner from the same fleece was 3 per cent., while for the New Zealand wools the largest difference was 6 per cent. These differences were calculated on the basis of raw wool weight.

(3) The difference in shrinkage between two fleeces of the same breed of sheep grown in the same location was found to be as great as 9.5 per cent. The results of such tests upon 13 different breeds of sheep showed a mean variation of only 4.5 per cent. in the shrinkage.

PROTECTION OF LIFE AND PROPERTY AGAINST LIGHTNING.

By O. S. Peters.

This paper is a report of a survey of statistical data relating to life and property hazards from lightning, and also of existing methods of protection against lightning. The field covered does

not include electrical power and signal systems. In the course of preparation of the paper an examination was made of the available literature on the subjects of lightning phenomena and protection against lightning, and of the reports of fire marshals and insurance companies. In addition to this a considerable amount of data was obtained from the reports of the Census Bureau, and manufacturers of lightning rods were asked to submit their opinions, and the results of their experiences, as to how a system of lightning rods should be installed. Appendixes are included in the paper, giving rules concerning the installation and maintenance of lightning rods which have in some cases been followed in Germany, England, and the United States, and also rules for first-aid treatment in cases of persons injured by lightning.

The chief facts disclosed by the information obtained in the course of the inquiry may be summarized briefly as follows:

(1) The property loss by lightning for the entire United States is approximately eight million dollars per year, of which by far the greater part occurs in rural districts.

(2) During each year there are approximately 1500 persons affected by lightning stroke in the United States, one-third of this number being killed and the rest subjected to injuries which in many cases are permanent. About nine-tenths of these accidents occur in rural districts.

(3) Such evidence as is available on the effectiveness of lightning rods indicates that, taking rods as they come in the general run of installations, they reduce the fire hazard from lightning by 80 to 90 per cent. in the case of houses, and by as much as 99 per cent. in the case of barns. The same is undoubtedly true of other buildings having characteristics similar to those of barns and houses.

(4) With regard to the proper metal for lightning rods, it may be said that the differences of resistivity of the metals ordinarily available for lightning rods are not great enough to make one metal preferable to another. Resistance to atmospheric and soil corrosion is the chief essential to be considered.

(5) Extended metallic masses on or within a building must be made a part of the lightning rod system, with a possible exception, however, in the case of metallic masses within the building which do not come near the roof and are at a distance of ten feet

or so from the rods. Gas-pipes should be avoided in erecting lightning conductors if possible, but if they are so located that it is impossible to keep at a distance of ten feet or more, they should be electrically connected to the rods at several points, connected to earth within the building, and well bonded around the gas meter.

(6) The maximum current in a lightning flash may, in some cases, be more than 20,000 ampères.

(7) Each flash of lightning consists, in most cases at least, of a number of consecutive discharges along the same path, with short time intervals between them. The duration of each of the consecutive discharges is of the order of $\frac{1}{10000}$ second. The best obtainable evidence points to the fact that these consecutive discharges are unidirectional and of steep wave-front.

(8) The heating effects of a lightning stroke on a rod of ordinary size, *i.e.*, a rod weighing about 0.5 kg. per meter, are not likely to be appreciable except at the place where the stroke enters the rod, or at high-resistance joints.

(9) Good mechanical construction in a lightning rod system is a prime essential to permanency. Rods are subject to severe strains from wind, snow, and ice, thermal expansion and contraction; and, in the event of a stroke of lightning, to electromagnetic stresses, so joints must be strong and the rod securely fastened to the building.

(10) The resistance of the earth connection should be made as low as practicable. In practice there is no chance of getting too low a resistance. On the other hand, a resistance which rises above 15 or 20 ohms at any time should be considered as excessively large on account of the potential drop which may possibly be set up in the event of a stroke.

(11) When a system of lightning rods is installed aërial terminals with points should be placed at all chimneys, gables, points, or other projections toward which a stroke of lightning might be directed. This is because a point cannot be relied upon to protect objects other than that upon which it is placed.

(12) Down conductors should be run in such a way that a stroke on any aërial terminal on a structure will have two or more widely-separated paths from the foot of the aërial terminal to earth. One path to earth has been found to be unsafe, and more than two are preferable.

(13) It has been shown photographically that the path of a

lightning discharge may be shifted by the wind as much as 10 metres or more during the period between the initial and final discharge. For this reason it is advisable not to allow too great an expanse of flat roof to be exposed without aërial terminals.

(14) The return on an investment in lightning rods may be expected in two ways: in a sense of personal security from lightning, and in actual security to life and property. The property loss from lightning is not sufficient to cause universal protection against lightning to be a paying investment. Protection against lightning is justified as an investment only where risk to human life is involved, or where the property risk is great enough to make protection against lightning more economical than insurance.

(15) With regard to personal safety from lightning, it may be said that no place to which a person may ordinarily retire can be considered as absolutely safe. The only places which can be considered as closely approximating absolute safety are in a building completely surrounded by a metal network, in a steel frame building, or in an underground chamber. A high degree of safety, however, may be found in a well-rodded building; the next degree of safety is undoubtedly to be found in an unprotected house, which may be considered as far preferable to the open or unprotected outbuildings.

Use of the Flame Arc in Paint and Dye Testing. W. R. MOTT. (*Electrochemical Society*, September 16–18, 1915.)—The white-flame arc at 25 ampères affords light at two feet (60 cm.) distance more intense than summer sunlight, and, unlike sunlight, this white-light is exactly reproducible and available 24 hours in every day. Sunlight varies continually, due to shifting solar position and changing atmospheric conditions. Dyes and paints have generally been tested in sunlight because, until the invention of the high-amperage white-flame arc, sunlight was the most intense light practically available. Some good work has been done with the pure carbon arc; but these are limited in value, the first by low intensity and the second by the source of the action being ultra-violet light, which is often different from the action of ordinary light.

The high-amperage white-flame arc has forced out all other forms of illumination as the cheapest, most powerful source for photo-engraving. It is taking its legitimate field for blue-printing, for photographic studio work, and for laboratory and industrial manufacture of chemicals by light.

NOTES FROM NELA RESEARCH LABORATORY,

THE MODE OF ACTION OF ULTRA-VIOLET RADIATION IN INJURING THE REFRACTING MEDIA OF THE EYE.[1]

By W. E. Burge.

THE refracting media of the eye, cornea, lens, etc., are composed of cells. The most important constituent of the cell is a colloidal material, protein. Egg-white is a good example of a protein. It is known that egg-white is converted into an opaque coagulum on exposure to ultra-violet radiation, just as it is when it is heated to 100° C.

Free swimming unicellular organisms, paramecia, were exposed to the radiation from a quartz mercury burner and observed under the microscope during the exposure. The normal organisms are transparent; those exposed became very granular and opaque. The conclusion may be drawn that ultra-violet radiation injures or kills living cells by coagulating the protoplasm or living material of the cells.

A normal excised crystalline lens was placed between two quartz plates and pressed into a thin layer by squeezing the plates together. By means of a quartz spectrograph the spectrum from a quartz mercury burner was focused on the layer of transparent lens material for 30 hours. At the end of this time it was as transparent as at the beginning of the experiment. However, when the preparation was immersed in a 0.1 per cent. calcium chloride solution four bands of coagulated lens protein appeared where the bands of the spectrum had been focused. These bands are of wave-lengths 249 $\mu\mu$, 254 $\mu\mu$, 265 $\mu\mu$, and 280 $\mu\mu$, respectively.

The further conclusion may be drawn that the short wave-lengths of the spectrum coagulate the living material of the cells by changing this material in such a way that certain salts (*e.g.*, those of calcium) can combine with it to form a precipitate or

---

* Communicated by the Director.

[1] To appear in *Transactions, Illuminating Engineering Society* and *The Ophthalmic Record.*

coagulum, and that the effective wave-lengths in case of the quartz mercury arc used are between 249 $\mu\mu$ and 280 $\mu\mu$ inclusive.

The great resistance of the normal lens to the coagulative effect of ultra-violet radiation is accounted for by the fact that normally there are present in the lens practically no salts to combine with the protein changed by exposure to the short wave-lengths of the spectrum to form a coagulum. The fact that it has been possible to produce an opacity of the lens or cataract in fish living in solutions of certain salts by exposure to ultra-violet radiation, whereas this could not be done with fish living in tap-water, would seem to support this hypothesis. Using frogs, it has been shown also that the effectiveness of ultra-violet radiation in producing anterior eye trouble is greatly increased by solutions of the salts of calcium or of magnesium or sodium silicate. These salts were used because quantities greatly in excess of the normal had been found in human cataractous lenses.

"OVERSHOOTING" IN TUNGSTEN LAMPS.[1]

By A. G. Worthing.

IN this work the screen of a Lummer-Brodhun photometer head was illuminated on one side by the lamp investigated for "overshooting," and on the other side by an adjustable comparison lamp. By means of a pendulum device, the circuit containing the lamp being investigated was closed; and then, following a desired heating interval for its filament, the photometer field was momentarily (0.02 second to 0.05 second) exposed to the observer's eye. Repeated trials in adjusting the voltage of the comparison lamp, following a definite cooling interval (about 12 seconds) led to an approximately instantaneous determination of the luminous intensity of the lamp being investigated. Determinations for various heating intervals gave the luminous intensity of the lamp on being lighted as a function of time. Any "overshooting" in luminous intensity and its magnitude may be readily seen from a plat of the data.

A 1.1-mil filament in an evacuated bulb (25 watts, 110 volts) in a 110-volt storage battery circuit showed a slight "overshooting," which may possibly, in the light of some other work, be

[1] To appear in *Lighting Journal.*

ascribed to the slower relative rate in the heating of the cooled ends as compared with the central portions of the filament. A 6.5-mil gas-filled lamp with a hair-pin filament showed "overshooting" amounting to about 6 per cent.

Taylor's [2] photographic observations have been verified qualitatively, though quantitatively much less of an "overshooting" has been found than one would expect from his work.

Manufacture of Aluminum in the United States. Electrometallurgical Industries as Possible Consumers of Electric Power. D. A. LYON and R. M. KEENEY. (*Proceedings Electrochemical Society*, September 17, 1915.)—All aluminum manufactured to-day is produced by an electrometallurgical process, either by the Heroult process or by the Hall process, both of which are essentially the same. In the United States the Hall process is used, and in Europe the Heroult process.

The production of aluminum in the United States has increased materially since 1912, but exact figures are difficult to obtain (owing to statistics being given for recent years as consumption). The consumption in 1913 amounted to 72,379,090 pounds, of which 23,000,000 pounds were imported during the calendar year. The actual production in 1913 in the United States has been estimated at 65,000,000 pounds and to-day probably 150,000 horse-power is in use for this purpose.

Until recently the production of aluminum in the United States was entirely controlled by the Aluminum Company of America, owners of the Hall patents, which have now expired. On the expiration of these Hall patents in the United States a company was formed by French financiers interested in L'Aluminum Française, under the name of the Southern Aluminum Company. A plant is in course of construction at Whitney, N. C., on the Yadkin River, where a total development in high water of 100,000 horse-power is possible, although the average power will be 45,000 horse-power. The capacity of the plant to be erected will be 20,000,000 pounds of aluminum per annum. This company continued its construction work up to the outbreak of the European war, when it became embarrassed by the then existing financial condition and so was obliged to discontinue its work. Such being the case, the Aluminum Company of America is the only real producer. Some second quality material is put on the market by concerns which simply re-melt scrap and junk.

In Europe the aluminum industry has progressed as rapidly as in the United States. Europe, in 1913, produced about three times as much as the United States, but this country leads in individual production, with France second.

---

[2] *Elec. World*, 51, pp. 859 and 1046, 1908.

Some Facts About Limestone. (*United States Geological Survey Press Bulletin No. 233,* September, 1915.)—A ton of absolutely pure limestone would burn to a little over half its weight of lime, or about 1120 pounds, which, counting 80 pounds to a bushel, would give 14 bushels of lime to a ton. The weight of the burned product, however, generally averages more than this, owing to impurities in the limestone and also because in ordinary kilns the combustion is not complete enough to drive off all the carbon dioxide.

A cubic foot of limestone averages in weight from 145 to 175 pounds, which would make a ton of limestone contain from 11 to 14 cubic feet.

The Thermo-electric Properties of Carbon. W. C. MOORE. (*The Journal of the American Chemical Society,* vol. xxxvii, No. 9, September, 1915.)—This study of the thermo-electric properties of carbon offers evidence from a new viewpoint that amorphous carbon is not a single definite substance. The thermo-electric properties of this material are reproducible for any one carbon, but they may vary with the temperature and are determined by the kind of raw material used and the manufacturing history of the carbon. The fact that with some varieties of arc carbons a considerable temperature range of constant electromotive force was found indicates the possibility of a transition interval for these carbons.

Recent Improvements in the Electric Lighting of Steam Railroad Cars. R. C. LANPHIER. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxiv, No. 8, August, 1915.)—This paper deals with the axle system of electric lighting for steam railroad cars, and describes recent improvements in control systems for obtaining proper voltage from the generator under all conditions and proper regulation of battery charge to conserve the life of the storage battery. Methods of control depending upon *voltage* of the battery have not been successful. Since the beginning of 1914, extensive use has been made of systems of control of battery charge based upon the actual input and output in ampère-hours, and one such system which has proved successful is described.

In the development of the system of control by ampère-hour meter, tests were made by means of a special graphic recording ampère-hour meter which gives a complete record of the treatment received by a storage battery with any axle generator system. Actual records from long runs are reproduced to show the results obtained in the operation of the system of control of charging by ampère-hour meter. With this system the battery has minimum work to do, in most cases operating between points of 75 or 80 per cent. of full load and full charge, and the lighting load is put on the generator as much as possible.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

ARTIFICIAL ILLUMINANTS FOR USE IN PRACTICAL PHOTOGRAPHY.

By C. E. Kenneth Mees, D.Sc.

[ABSTRACT.]

ARTIFICIAL illuminants can be used in negative making for portraiture, cinematograph work, and photo-engraving. For portraiture diffused sources are necessary, and either a large source, such as that given by a bank of Cooper-Hewitt lamps, must be used or the light must be reflected from a large area.

In cinematograph work about a quarter kilowatt per square foot of stage is used, the usual arrangement including the use of Cooper-Hewitt lamps overhead and at one side of the stage, and arcs in front.

For photo-engraving an arc lamp is hung on each side of the copy-board, most engravers using flame carbon arcs.

For printing papers the enclosed arc is used for silver papers, while for platinum the Cooper-Hewitt lamp is satisfactory. In printing fish-glue on metal it is important that a small source of light should be used in order to get sharp definition of the dots, and the printing should be as far away as possible.

The following illuminants are recommended for portraiture: flame arcs, Cooper-Hewitt lamps, and nitrogen tungsten lamps; for cinematograph work, the Cooper-Hewitt, quartz arc, and flame arc; for photo-engraving, the enclosed arc and flame arc; for silver printing, the enclosed or flame arcs; for platinum printing, the Cooper-Hewitt lamp.

The photographic efficiency of artificial illuminants depends upon their quality and upon their visual efficiency, but must be considered from the point of view of the materials used, which materials are of three chief kinds: (1) panchromatic materials sensitive to the whole spectrum and used with filters to give a rendering similar to that seen by the eye, or for color photography; (2) ordinary materials having their maximum sensitiveness in the blue-violet; (3) materials sensitive only to the ultra-violet.

For panchromatic materials the efficiency of the illuminant will

* Communicated by the Director.

depend almost entirely upon its visual efficiency, while for ordinary materials the chief point of importance is the efficiency in the blue-violet, but, since the latitude and freedom from halation increase with shorter wave-lengths, it is better to use light sources having their maximum near 400 $\mu\mu$ rather than near 470 $\mu\mu$. It is pointed out that nearly all artificial illuminants have application in some branch of photography or other.

Research Laboratory,
September 14, 1915.

THE RETINAL SENSIBILITIES RELATED TO ILLUMINATING ENGINEERING.[1]

By P. G. Nutting, Ph.D.

THE fundamental principles of good lighting are derived primarily from the properties of the human retina, the eye being the sole means of judging whether illumination is good or defective.

Of chief importance is the magnitude of the brightness sensation as a function of the flux density of light at the retina. This cannot be directly measured, but sensibility, its derivative, may be readily determined at all working intensities and formulated in the function

$$S = S_m + (1 - S_m)(B/B_o)^n$$

For threshold sensibility $S_m = 000022$, $B_o = 0000017$ millilamberts, and $n = 0.49$ for white light. For photometric sensibility (König's data), $S_m = 0.0175$, $B_o = 0.0090$ (unit 0.0036 m.l.) and $n = 0.45$. These formulæ for sensibilities integrate into the luminous sensation scale

$$L = K \log (1 + S_m(I^n I_o^{-n} - 1))^{1/n}$$

In practical engineering problems interest is centred on four chief levels of brightness. For these the important data are the following:

	Mean brightness level (millilamberts)	Photometric sensibility	Threshold (millilamberts)	Relative sensibility Threshold	Contrast	Glare
1. Exterior daylight ...	1000	0.0175	0.35	1	1	1
2. Interiors in daylight	10	0.030	0.017	21	59	200
3. Interiors at night ...	0.1	0.123	0.0014	251	1430	18000
4. Exteriors at night ..	0.001	0.79	0.00011	3090	22300	160000

[1] Abstract of a paper delivered at the Washington Convention of the Illuminating Engineering Society.

The numbers of the last three columns are inversely proportional to the threshold, contrast, and glare lumens.

The rates at which sensibility changes from one level to another have been redetermined with improved apparatus for a number of subjects with results agreeing with previous data summarized in Helmholtz, "Physiolog. Optik," 3d Edition. Great attention has been given to determining the rate during the first few seconds of adaptation.

The size of pupil in a normal eye viewing a field of given brightness is roughly as follows:

Brightness ($\log_{10}$ m.l.)	−5	−4	−3	−2	−1	0	1	2	3
Diameter of pupil (mm.)	6.9	5.8	5.0	4.3	3.8	3.3	2.9	2.5	2.2
Area of pupil	37.4	26.4	19.6	14.0	11.3	8.5	6.6	4.9	0.8

Local adaptation was found to be pronounced with the field limited by a black-lined tube with an iris diaphragm at the distant end and adaptation to a fixed brightness of 0.1 millilambert. The instantaneous thresholds found were:

Solid angle of bright spot	6.0	.43	.016	.0026	.00016	.000041
Instantaneous threshold	.0019	.0020	.0042	.0143	.030	.034 m.l.

The angular size of the fovea is 0.016 steradian; no irregularity in the curve is noticeable at this point. The great decrease in sensibility indicates that adaptation is extremely localized and that the eye is not fitted to function properly when only the object viewed is illuminated. This agrees with the known fact that when contrasts are extreme, as in machine shops, a much higher level of illumination is required than in rooms lacking extreme contrasts.

The relative visibility of radiation of different wave-lengths has recently been determined by Ives, by Nutting, and by Hyde. The best data fit the formula

$$V = V_m R^a E^a (1 - R)$$

in which $a = 181$ and $R = \lambda\text{max}/\lambda$, λmax being $0.555\ \mu$. The value of V_m (Ives and Coblentz) is 0.00140 watt per lumen. The formula holds well throughout all the more luminous part of the spectrum from 0.48 to 0.67 μ. When multiplied by the spectral energy function of a complete radiator or other body and integrated, it gives total light flux density as a function of temperature.

Sensibility to differences in wave-length (hue sensibility)

varies considerably throughout the spectrum and from one subject to another. Averaging the data for eighteen subjects gives:

Wave-length	440	455	492	534	581	621	635 μμ
Perceptible difference.	2.47	2.93	1.36	3.34	1.38	3.75	3.00 μμ

The integral of the hue sensibility gives the fundamental hue scale. With the entire spectrum from violet to red taken as 10 units, the values of the scale are:

Hue scale	0	1	2	3	4	5	6	7	8	9	10
Wave-length	396	421	468	485	501	532	560	577	598	635	700

There are in all about 180 just noticeably different hues in the spectrum from violet to red, and about 20 more from red to violet through purple. The amount of white that may be mixed with hues of various purities before it becomes noticeable is approximately as follows:

Per cent. white.....	0	10	20	30	40	50	60	70	80	90	100
Per cent. hue.....	100	90	80	70	60	50	40	30	20	10	0
Impurity noticeable	4.7	4.6	4.5	4.4	4.2	4.0	3.7	3.4	3.0	2.5	2.1

There are about 20 just noticeably different steps between pure hue and pure white. The effect is nearly or quite independent of both the hue and the intensity.

Research Laboratory,
September 10, 1915.

RELATIVE PHOTOGRAPHIC AND VISUAL EFFICIENCIES OF ILLUMINANTS.

By L. A. Jones, M. B. Hodgson, and Kenneth Huse.

[ABSTRACT.]

CERTAIN relations exist between the visual and photographic efficiencies of various illuminants when used in connection with the three typical classes of photographic plates. The classification of photographic materials is made from the standpoint of their spectral sensibilities, the three types being ordinary, orthochromatic, and panchromatic. The work is confined to high-speed materials used for negative making, no attempt being made to cover the entire field of sensitive materials.

The method adopted for obtaining the desired results is essentially that used in the determination of plate speeds, and is

based upon the fact that if the plate speed is kept constant and the illuminant varied the "inertia" value obtained will be inversely proportional to the relative photographic efficiency of the source.

The photographic efficiency of sunlight is taken as 100 per cent., and the efficiencies of other illuminants are expressed relative to that of sunlight.

Relative photographic efficiency is designated by the symbol E_r, this term representing the ratio between the effects produced on a plate when given equal exposures (measured visually in metre-candle seconds) to sunlight and to another source. Thus, if for a given source $E_r = 50$ per cent., then in order to obtain a given effect on a plate twice as great an exposure must be given when using that source as would be required in case sunlight were used.

The results obtained are shown in Table VII.

TABLE VII.

Source	Visual efficiency Lumens / Watt	Photographic materials: Ordinary E_r	Orthochromatic E_r	Panchromatic E_r
1. Sun	*150	100	100	100
2. Sky	....	181	155	130
3. Acetylene	*.7	30	44	52
4. Acetylene—Screened	*.07	81	85	89
5. Pentane	*.45	18	28	42
6. Mercury arc—Quartz	*40.0	600	500	367
7. Mercury arc—Nultra glass	*35.0	218	195	165
8. Mercury arc—Crown glass	*37.0	324	275	249
9. Carbon arc—Ordinary	*12.0	126	112	104
10. Carbon arc—White flame	*29	257	234	215
11. Carbon arc—Enclosed	*9.0	175	177	165
12. Carbon arc—"Artisto"	*12.0	796	1070	744
13. Magnetite arc	*18.0	106	115	82
14. Carbon—Glow lamp	2.44	23	32	42
Carbon—Glow lamp	3.16	25	35	45
15. Tungsten—Evacuated	8.0	33	41	50
Tungsten—Evacuated	9.9	37	45	53
16. Tungsten—Nitrogen filled	16.6	56	62	70
Tungsten—Nitrogen filled	21.6	64	68	76
17. Tungsten—Blue bulb	11.0	108	99	106
18. Mercury—Cooper-Hewitt	*23	316	354	273

The values given in Table VII are relative efficiencies on a basis of equality in illumination. Since the photographic effi-

ciencies in terms of energy consumption are of considerable interest, the values obtained have been reduced to that basis and are given in Table VIII.

The inertia values (i) obtained from the original measurements are expressed in exposure units; that is, metre-candle seconds. The luminous flux incident upon unit area (1 square centimetre) at a metre distant from a source of 1 mean spherical candle-power is $\frac{4\pi}{4\pi r^2} = \frac{1}{100^2}$ lumens. This is the value of the luminous flux incident upon a unit area of a surface at which the illumination is 1.0 metre-candle. Then $i_e = \frac{i \text{ (in m. c. s.)}}{100^2}$ is the inertia value expressed in $\frac{\text{lumen seconds}}{\text{cm.}^2}$

Now, if the efficiency of the source used is E (in $\frac{\text{lumens}}{\text{watt}}$), the value remains the same when expressed in $\frac{\text{lumen seconds}}{\text{watt second}}$, $\frac{1}{E}$ is the efficiency in $\frac{\text{watt seconds}}{\text{lumen seconds}}$, and

$$i_e = \frac{i \text{ (in m. c. s.)}}{100^2} \times \frac{1}{E} = \frac{\text{watt seconds}}{\text{cm.}^2}$$

$$i_e = \frac{i \text{ (in m. c. s.)}}{100^2} \times \frac{10^7}{E} = \frac{\text{ergs}}{\text{cm.}^2}$$

i_e is, therefore, the inertia value expressed in ergs consumed at the source per cm.^{2} at the plate. This value is inversely proportional to the photographic efficiency of the source when used on that particular plate. The photographic efficiency may be obtained, therefore, by taking the reciprocal of i_e.

In order to make the results obtained on different plates comparable with each other it is necessary to use some source as a standard. Sunlight is used as before, its efficiency being taken as 100 on each plate.

The values of visual efficiency for many sources were not measured directly, but were estimated from the best available data found in the literature on the subject. Stars indicate the values so obtained. The values tabulated in Table VIII are:

$$E_e = \frac{100\, i_e \text{ (for sun)}}{i_e \text{ (for particular source)}}$$

TABLE VIII.

Source	Efficiency Lumens / Watt	Photographic materials: Ordinary E_e	Orthochromatic E_e	Panchromatic E_e
1. Sun	150	100	100	100
2. Sky	...			
3. Acetylene	.7	0.14	.21	.24
4. Acetylene—Screened	.07	0.037	.040	.042
5. Pentane	.45	0.053	.086	.13
6. Mercury arc—Quartz	40	158	132.0	99
7. Mercury arc—"Nultra"	35	50	46	39
8. Mercury arc—Crown	37	79	68.0	62
9. Carbon arc—Ordinary	12	10.0	9.0	8.5
10. Carbon arc—White flame	29.0	52	45	2
11. Carbon arc—Enclosed	9	11	11	10
12. Carbon arc—"Artisto"	12	62	86	60
13. Magnetite arc	18	12	14	10.0
14. Carbon—Glow	2.44	.37	.52	.68
Carbon—Glow	3.16	.51	.74	.95
15. Tungsten—Vacuum	8.0	1.74	2.2	2.7
Tungsten—Vacuum	9.9	2.41	3.0	3.5
16. Tungsten—Nitrogen	16.6	6.1	6.8	7.7
Tungsten—Nitrogen	21.6	8.9	9.8	11.0
17. Tungsten—Blue bulb	8.9	5.5	5.2	5.6
Tungsten—Blue bulb	11.0	7.8	73	7.9
18. Mercury—Copper-Hewitt	23.0	47	54.2	42

The values of E_r given in Table VII enable us to pick from any group of sources the one giving the greatest photographic efficiency, when used in connection with either of the three typical classes of photographic materials, for a fixed value of the *illumination.* The values in Table VIII, on the other hand, enable us to choose for either class of materials the source that is most efficient photographically, from the standpoint of *energy consumption.*

Monel Metal Mystery. ANON. (*The Brass World,* vol. xi, No. 8, August, 1915.)—The curious action of sea water and steel has caused the junking of a half-a-million-dollar pleasure yacht. Within a month or two much has been written and pictured concerning the auxiliary yacht *Sea Call,* that has had just six weeks of life and has had to be broken up to prevent sinking. The plating seems to have been fastened to the steel frames without the interposition of zinc, as is said to be the successful practice in the navy, and to-day, owing to the violent action of electrolysis, the ship is crumbling apart.

Mils versus Cubic Centimetres. J. P. REMINGTON. (*The Journal of the American Pharmaceutical Association,* vol. iv, No. 8, August, 1915.)—The new United States Pharmacopœia will authorize the use of the word "mils" to replace the word "cubic centimetres," and at first there will be undoubtedly some criticism and comment upon the change. The last United States Pharmacopœial Convention recommended publicity of changes of this kind in order that users of the United States Pharmacopœia would become familiar with the subject in advance.

The use of the word "mil" is not new, but the first use in a pharmacopœia occurred in 1914, when the British Pharmacopœia adopted it, and it is likely that its use will become universal in time, at least in the English language. "Mil" is, of course, the first three letters of the French name originally given to the thousandth part of a litre—millilitre. Very careful experiments by the government physicists have determined the fact that the cubic centimetre is larger than the millilitre by the inconsiderable fraction of 0.000027. In pharmacy, in chemistry, and in applied chemistry this difference is negligible, but every one must have regretted the cubic centimetre blot on the harmony and beautiful simplicity of the metric system.

Search for Tin in America. (*Bulletin 662-B,* United States Geological Survey.)—In view of the interest in an adequate tin supply for the United States and the discussion of the smelting of Bolivian ore on the Atlantic seaboard, and possibly on Puget Sound, the publication by the United States Geological Survey of a special bulletin on tin mining in Alaska is opportune. It is noteworthy, too, that specimens of stream tin were collected by Survey geologists in Alaska in 1900, before this metal was known to occur in the Territory. Soon after that time prospecting for steam tin became active, and two years later a commercial production of tin ore was made.

The Survey was also closely identified with the finding of lode deposits of tin. In 1903, two prospectors brought to Survey geologists in Alaska some specimens of float from Lost River which they thought might be tin ore. All the specimens but one were worthless. From this one the geologists obtained tin by smelting it in a teacup in their cookstove, after which both the geologists and the prospectors went to Lost River and discovered a vein of lode tin. This lode on Lost River has since been extensively mined. Some of the Alaska tin ore has been reduced at Seattle, Wash., within the last two years.

The report just issued presents a review of other work by the Geological Survey and the reëxamination of the more important tin deposits by Geologist Henry M. Eakin.

The total tin production for the period 1902–1914 amounted to 526 tons of metallic tin, valued at $380,000. The Alaskan tin ores have heretofore been shipped for reduction to Swansea (Wales) and Singapore.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

RADIOGRAPHY OF METALS.

By Wheeler P. Davey.[1]

A PREVIOUS investigation [2] having shown the possibility of detecting blowholes in steel castings $^{9}/_{16}$ inch thick by means of radiographs made with a Coolidge tube, the present problem is to get data for determining the length of exposure necessary for any given thickness, and to find the limiting size of air inclusion which can be demonstrated in a given thickness.

It is found that the effective penetration of X-rays at the voltage corresponding to a 13-inch spark gap between points is a little greater than for the 11-inch gap, but about the same as for the 15-inch. The amount of exposure required, however, decreases as the voltage is increased. The clearness of the picture is not appreciably less at the higher voltages, in spite of the apparent opportunity for scattering.

From the darkening of X-ray plates exposed beneath varying thicknesses of metal and at different voltages, the following formulæ are derived, in which E is the exposure required for good results, in milliampère minutes, and X the thickness of the steel in centimetres:

For a 15-inch spark gap:

$$E = \frac{1}{10} \log_{10}^{-1} 0.71X$$

For a 13-inch spark gap:

$$E = \frac{3}{20} \log_{10}^{-1} 0.71X$$

For an 11-inch gap (approximately):

$$E = \frac{3}{5} \log_{10}^{-1} 0.82X$$

---

* Communicated by the Director.

[1] *General Electric Review*, 18, 795–800, August, 1915.

[2] "X-ray Inspection of a Steel Casting," *General Electric Review*, 18, 25–7, January, 1915.

By exposures of an air wedge varying in thickness from $^{9}/_{64}$ inch to 0, between two plates of metal, it was found that an air inclusion 0.021 inch thick could be detected in 1¼ inches of steel or 0.007 inch thick in ⅝ inch of steel.

Radiographs are given showing autogenous welds in ½ inch steel and the difference in appearance between good, underheated, and burned welds, the last exhibiting a porous structure.

Blowholes, slag inclusions, porous spots, etc., may be demonstrated radiographically, though no fluoroscopic screen sensitive enough for direct vision is yet available. The formulæ show that with the voltage now used it is not yet practicable to test in this way thicknesses of steel greater than ½ inch because of the time required. The technic employed is described in detail.

THE MELTING-POINT OF TUNGSTEN.

By Irving Langmuir.[1]

OBSERVATIONS made during the investigation of the characteristics of tungsten filaments in evacuated and gas-filled lamps indicated that the intrinsic brilliancy of solid tungsten, at a temperature just below the melting-point, is about 7200 international candles per square centimetre. This should correspond, according to Rasch's equation, with constants determined by Nernst, and an emissivity determined by von Wartenberg, Coblentz, and von Pirani, to a melting-point of 3540° K. instead of 3200 to 3300° K., which had appeared, from a consideration of the results of previous investigations to be the most probable value.

An analysis of the sources of error in the method used showed no reason to suspect an error greater than 50°.

It was found repeatedly, however, that the presence of minute amounts of hydrocarbon vapors, such as are given off by vaseline or stopcock grease at room temperature in vacuum, not only lowers the melting-point and raises the resistance, but also increases the emissivity. This factor has entered into many of the methods heretofore used.

In view of the lack of agreement in the values given, it was decided to redetermine the melting-point by methods which should eliminate former sources of error.

---

[1] *Physical Review*, 6, 138–57, 1915 (issued in August).

The two methods employed consisted of (1) determining the black body melting-point of large filaments in nitrogen, and obtaining the emissivity from helically-wound filaments of various sizes in vacuum and in nitrogen, and (2) measuring the brilliancy of a surface of molten tungsten and simultaneously determining the brilliancy of the image of a second surface of molten tungsten reflected in the first, thus determining the reflectivity of the molten metal directly.

A pyrometer of the Holborn-Kurlbaum type was used with several nearly monochromatic screens in the eyepiece of the telescope. The equivalent monochromatic wave-lengths for these screens were estimated by direct spectroscopic examination, and also by measuring the relative brilliancy of a large nitrogen-filled lamp with a straight filament, at a series of different temperatures, by means of a Lummer-Brodhun photometer, using the different screens successively in the eyepiece.

The pyrometer was calibrated by first determining the relation of the luminous intensity of the pyrometer filament to the current flowing through it. This was done by means of rotating sectors, and by comparison with the nitrogen-filled lamp photometered through the three screens over the range of temperatures from 1850° to 3040° K.

Next the currents through the pyrometer filament corresponding to several fixed temperatures were determined from the melting-points of gold, copper, and platinum. The pyrometer was also checked by a heavy filament vacuum tungsten lamp previously calibrated against a black body furnace at the melting-points of gold and palladium.

The emissivity of solid tungsten was obtained by determination of the relative brilliancy of the brightest and darkest portions of a helically-wound filament in nitrogen. The best value appeared to be 0.485 or less for $=0.537$. The emissivity of molten tungsten measured by the method mentioned below was found to be 0.425, and that of the solid distinctly higher. Hence 0.46 was adopted as the most probable value for $\lambda = 0.667$.

The melting-point of short, single, hair-pin filaments in bulbs containing pure, dry nitrogen was determined on the pyrometer by raising the temperature. The nitrogen atmosphere prolonged the life of the filaments at the highest temperature so considerably that it was possible to approach the melting-point very slowly,

and the actual melting lasted several seconds. After burn-out the bulbs were opened and the absorption coefficient determined.

The emissivity and melting-point of tungsten were also determined from an alternating arc between tungsten electrodes in nitrogen. At sufficiently high current density the ends of both electrodes formed molten convex surfaces showing multiple reflections of the two electrodes, and could be maintained in this condition for half an hour or more. Repeated measurements of the intrinsic brilliancy of the molten tungsten and of the successive images were made, giving a direct measurement of the reflectivity and black body temperature, the arc being practically non-luminous with an intrinsic brilliancy less than 1 per cent. of that of the electrodes. The emissivity thus obtained was 0.425 for $\lambda = 0.667$, and the true melting-point derived therewith from the pyrometer measurements 3566° K.

The values for the melting-point by the several methods are then as follows:

1. Total photometric method ..... 3540° K.
2. Filaments by pyrometer method ..... 3332° K.
3. Arc electrodes by pyrometer method ..... 3566° K.

A consideration of the probable errors indicates that the best value is 3540° K. ± 30°.

HARD X-RAYS.

By W. D. Coolidge.[1]

THE factors determining the hardness or penetrating power of X-rays are mentioned, special emphasis being laid upon the fact that with any given target the penetration depends entirely upon the impressed voltage and increases with it, without relation to the design of tube, vacuum, or current passing. The penetration hitherto attainable has been limited by the difficulty of producing a tube that can be run continuously on very high voltages.

Recent work indicates that with suitable design a hot cathode tube with sufficiently high vacuum can be built to operate at any voltage now available. The present commercial tube can be used

[1] *American Journal of Röntgenology*, **2**, 723–5, April, 1915 (issued in August).

on voltages up to that indicated by a 10-inch spark between points. Experimental tubes, modified from this type, have already been run backing up a 20-inch spark, which corresponds to about 200,000 volts, and the penetration is being determined for comparison with X-rays from radio-active substances. Rutherford [2] has pointed out that on the basis of the quantum theory it can be easily shown that 180,000 volts applied to an X-ray tube should give radiations of a penetration equal to that of the hard gamma rays from radium C, which are only half absorbed by 6 cm. of aluminum.

Rays of this penetration should be of extreme value in connection with the testing of metals as carried out by Dr. Davey, of this laboratory.

In the field of therapeutics it will be possible to get essentially homogeneous rays by filtering, and in this way find out whether rays of a certain frequency are especially suited for any specific purpose.

Wireless Telegraphy for Railroads. J. L. HOGAN, JR. (*Electrical World*, vol. 66, No. 11, September 11, 1915.)—Since the beginning of experiments in wireless telegraphy for railroad service by the Delaware, Lackawanna and Western Railroad in 1913, there has been ample opportunity to prove the value of radio equipments for provision of an emergency telegraph service. When wires fail because of sleet storms, washouts, wreck, or other line-destroying occurrences, it is found not only convenient but extremely valuable to be able to communicate between the main dispatching points of the railroad by means of wireless. On several occasions the Delaware, Lackawanna and Western has averted extended tie-ups by such use of the radio equipments, and, following these practical demonstrations, installations have been made at Hoboken, Scranton, Binghamton, and Buffalo. The Buffalo station at present has receiving apparatus only, pending completion of a new and permanent aërial structure. Hoboken is fitted with a 5-kilowatt Marconi set and has a 400-foot tower supporting the antennæ. At Scranton and Binghamton 2-kilowatt Marconi sets are installed with antennæ hung at an average height of about 175 feet. It is intended that a 400-foot tower shall be erected at Buffalo, so as to permit reliable signalling in both directions between that point and Hoboken. Experiments made between the National Electric Signalling Company's plant at Brooklyn and the Delaware, Lackawanna and Western station in Buffalo have shown that 10 kilowatts of sending power is ample to give good results over the distance of 400 miles under average daylight conditions.

---

[2] *Philosophical Magazine*, August, 1915.

Overhead Electrolysis and Porcelain Strain Insulators. S. L. FOSTER. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxiv, No. 8, August, 1915.)—There is a slight leakage of current from trolley wires to earth through insulated supports on all overhead construction, which, if not checked, permits a flow of current which gives rise to electrical separation of water into oxygen and hydrogen. The oxygen liberated acts vigorously upon the adjacent metal parts, which in time become badly corroded. This electrolytic action also seems to remove the galvanizing from live metal parts before attacking the iron. A partial remedy for this rusting of live galvanized wire is painting.

This electrolytic effect is also seen to take place over strain insulators when the creepage distance is insufficient. This indicates that a creepage distance proportional to the conditions met must be secured to stop the flow of current around the outside of the insulators. The author concludes that under fog conditions the insulator surface exposed for creepage is insufficient in our present standard devices.

Another form of overhead electrolytic action noticed in electric railway work is caused by the use of dissimilar metals in contact. Sulphuric acid and other fumes in the air and ozone from a nearby ocean are supposed to be the electrolytes that set up a local battery action at these points of contact. The logical remedy for this trouble is to use similar metal in contact. The paper then describes the troubles encountered in San Francisco due to these causes and the remedies that have been applied.

Great Lignite Resources of North Dakota. ANON. (*Northern Pacific Guidebook, United States Geological Survey.*)—Lignite underlies almost all the western part of North Dakota. It is estimated by the United States Geological Survey that the State contains the enormous amount of 697,000,000,000 short tons of lignite in beds over 3 feet thick and within 1000 feet of the surface, and it seems probable that there is workable lignite within this limit under every section of the land in the western part of the State. It is difficult to form an idea of a mass containing even 1,000,000 tons, and hence the figures given above are practically impossible of comprehension, but if the amount is put in the form of a cube a better conception of its magnitude may be obtained. The lignite of the State, if formed into one mass in the compact form in which it lies in the ground, would make a cube 5 miles long, 5 miles broad, and 5 miles high. Such a cube would cover nearly a township of land and would be almost as high as the highest mountain on the globe.

Much of the lignite, although of poor quality and at present used only in a small way, constitutes a vast fuel resource which will in time become of great value, not only to the individual citizens of the State but to the corporations that are seeking power for use in manufacturing or in transportation.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 1, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 1, 1915.

MR. G. H. CLAMER *in the Chair.*

The following reports were presented for final action:

No. 2628.—John Underwood and Company's Combined Typewriting and Calculating Machine. Hans Hansen and Frederick A. Hart recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium; the Edward Longstreth Medal awarded to John Underwood and Company.

No. 2636.—Lenker's L-E-Vation Rod. Final action on this report was deferred until next meeting.

No. 2643.—Street Locomotive Stoker. Clement F. Street recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, September 8, 1915.)

RESIDENT.

MR. JOHN F. MCCOY, care of Midvale Steel Company, Philadelphia, Pa.
MR. DAVID PEPPER, Commonwealth Building, Philadelphia, Pa.
MR. JOHN P. SYKES, care of The Baldwin Locomotive Works, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. JOSHUA L. BAILY, 1508 Walnut Street, Philadelphia, Pa.
PROF. W. S. FRANKLIN, Columbia University, New York, N. Y.
MR. J. M. GAZZAM, 265 South Nineteenth Street, Philadelphia, Pa.
PROF. I. M. RAPP, Department of Physics, Ursinus College, Collegeville, Pa.

NECROLOGY.

John T. Morris, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

BRAGG, W. H. and W. L.—X-rays and Crystal Structure. 1915.
BREARLEY, HARRY.—The Case-hardening of Steel. 1914.
FURMAN, F. DE R.—Steam Engines and Steam Turbines. 1915.
FURMAN, F. DE R.—Gasoline, Gas, and Oil Engines. 1915.
GOWLAND, WILLIAM.—Metallurgy of the Non-ferrous Metals. 1914.
HINCHLEY, J. W.—Chemical Engineering. Notes on Grinding, Sifting, Separating, and Transporting Solids. 1914.
International Catalogue of Scientific Literature.—Annual Issue, 1912. Chemistry D.
Jahrbuch für Photographie und Reproduktionstechnik. 1914.
JONES, F. D.—Planing and Milling. 1914.
JONES, F. D.—Turning and Boring. 1914.
Moody's Manual of Railroads and Corporation Securities, vol. 2. 1915.
OSTWALD, W.—Scientific Foundations of Analytical Chemistry. 1908.
PARSONS, J. H.—Introduction to the Study of Colour Vision. 1915.
Poor's Manual of Public Utilities, No. 3. 1915.
RHODES, H. J.—Art of Lithography. 1914.
SLOCUM, S. E.—Elements of Hydraulics. 1915.
WARBURG, E.—Physik. 1915.
WATSON, WILLIAM.—Experiments and Observations Tending to Illustrate the Nature and Properties of Electricity. 1746.

GIFTS.

American Institute of Metals, Transactions, vol. viii, 1914. Buffalo, 1915. (From the Institute.)
American Wood Preservers' Association, Annual Reports, 1912, 1913, 1914; Proceedings, 1915. Baltimore, Md., no date. (From the Association.)
American Society for Testing Materials, Membership List and Charter and By-Laws. Philadelphia, 1915. (From the Society.)
Astronomical and Astrophysical Society of America, Publications, vol. ii. Ann Arbor, Mich., 1915. (From the Society.)
Baylor University, Catalogue, 1914–15. Waco, Texas, 1915. (From the University.)
Berger, C. L., & Sons, Standard Instruments of Precision, 1916. Boston, 1915. (From the Company.)
Best William N., The Science of Burning Liquid Fuel. No place, 1913. (From the Author.)
British Association for the Advancement of Science, Report, 1914. London, 1915. (From the Association.)
British Columbia Department of Mines, Annual Report of Minister, 1914. Victoria, 1915. (From the Department.)
Bryn Mawr College, Calendar. Bryn Mawr, Pa., 1914. (From the College.)
Buffalo, Rochester and Pittsburgh Railway Company, Annual Report. New York, 1915. (From the Company.)

Canada Department of Agriculture, Appendix to the Report of the Minister of Agriculture, 1914. Ottawa, 1915. (From the Department.)

Canada Department of Mines, Memoir 74, A List of Canadian Mineral Occurrences; Products and By-Products of Coal. Ottawa, 1915. (From the Department.)

Canadian Pacific Railway Company, Annual Report. Montreal, 1915. (From the Company.)

Central University of Kentucky, Catalogue, 1914–15. Danville, Ky., no date. (From the University.)

Champion Rivet Company, Catalogue of Victor Boiler, Structural and Ship Rivets. Cleveland, no date. (From the Company.)

Cincinnati Water Works Department, Annual Report, 1914. Cincinnati, no date. (From the Department.)

Clark Brothers Company, Catalogue of Saw Mill Machinery. Olean, N. Y., no date. (From the Company.)

Colgate University, Bulletin. Hamilton, N. Y., 1914. (From the University.)

College of William and Mary, Catalogue, 1914–15. Williamsburg, Va., no date. (From the College.)

Colorado School of Mines, Catalogues, 1904–1916. Golden, 1904–1915. (From the School.)

Delaware College, Annual Catalogues, 1914 and 1914–15. Newark, no date. (From the College.)

Detroit Twist Drill Company, Catalogue No. 17 of Twist Drills. Detroit, Mich., no date. (From the Company.)

Electrical Testing Laboratories, Inc., Catalogue describing the work carried on by the Laboratories. New York, no date. (From the Company.)

Engineers' Club of Philadelphia, Directory, 1915. Philadelphia, no date. (From the Club.)

Fondation Teyler, Catalogue de la Bibliotheque, tome iv, 1904–1912. Haarlem, Holland, 1915. (From the Institution.)

General Fireproofing Company, Waterproofing Hand Book. Youngstown, Ohio, 1915. (From the Company.)

George Washington University, Catalogues, 1913, 1914, 1915. Washington, no date. (From the University.)

Hadfield, Sir Robert A., Sound Steel Ingots and Rails. London, 1915. (From the Author.)

Horsburgh and Scott Company, Blue Book on Gearing. Cleveland, Ohio, no date. (From the Company.)

India Meteorological Department, Rainfall of India, 1913. Calcutta, 1914. (From the Department.)

Indian Telegraph Department, Annual Reports, 1909–1914. Simla, 1910–14. (From the Department.)

Jellett, Edwin C., Germantown Gardens and Gardeners. Philadelphia, 1914. (From the Author.)

Lewis Institute, Register, 1912–13. Chicago, 1913. (From the Institute.)

Lincoln Memorial University, Catalogues, 1911–14. Cumberland Gap., Tenn., no date. (From the University.)

Locomobile Company of America, The Locomobile Book and Catalogue of Locomobile Worm Drive Trucks. Bridgeport, Conn., no date. (From the Company.)

Lowell Textile School, Bulletin, 1915–1916. Lowell, Mass., no date. (From the School.)

Manchester Steam Users' Association, Thirty-second Annual Report upon the Working of the Boiler Explosions Act, 1882, June 30, 1913, to June 30, 1914. Manchester, no date. (From the Chief Engineer.)

Montana State School of Mines, Catalogue, 1914–15. Butte, no date. (From the School.)

Morris, I. P. Company, Bulletin No. 3, Hydraulic Turbines. Philadelphia, no date. (From the Company.)

Municipal University of Akron, Catalogues, 1914, 1915. Akron, Ohio, no date. (From the University.)

National Tube Company, Catalogue J. Pittsburgh, Pa., no date. (From the Company.)

Oberlin College, Catalogue, 1914–15. Oberlin, Ohio, 1915. (From the College.)

Ohio Chief Inspector of Mines, Thirty-ninth Annual Report, 1913. Springfield, 1915. (From the Chief Inspector.)

Ohio Geological Survey, Fourth Series, Bulletin 18, Building Stones of Ohio. Columbus, 1915. (From the Survey.)

Ohio University, Catalogues 1914, 1915–16. Athens, 1914, 1915. (From the University.)

Ohio Wesleyan University, Catalogues, 1912, 1913, 1914. Delaware, no date. (From the University.)

Pennsylvania Department of Labor and Industry, Commissioner's Report, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania State College, Annual Report, 1912. Harrisburg, 1913. (From the State Librarian.)

Philadelphia Bureau of Highways and Street Cleaning, Report, 1914. Philadelphia, no date. (From the Bureau.)

Philadelphia Bureau of Surveys, Annual Report, 1914. Philadelphia, no date. (From the Bureau.)

Philadelphia Department of City Transit, Annual Report, 1914. Philadelphia, no date. (From the Department.)

Pierce, Butler and Pierce Manufacturing Corporation, Pierce Fitters Book. Syracuse, N. Y., no date. (From the Company.)

Porter, H. K. Company, Catalogue of Steam Locomotives. Pittsburgh, Pa., no date. (From the Company.)

Pratt Institute, Catalogue, 1914–15. Brooklyn, N. Y., no date. (From the Institute.)

Princeton University, Catalogue, 1914–15. Princeton, 1914. (From the University.)

Purdue University, Catalogues, 1911–12, 1912–13, 1913–14, 1914–15. Indianapolis, 1912–1915. (From the University.)

Queensland Acting Secretary for Mines, Annual Report, 1914. Brisbane, 1915. (From the Secretary.)

Railway Library and Statistics, 1914. Chicago, 1915. (From Mr. Slason Thompson.)

Rensselaer Polytechnic Institute, Catalogue, 1915, Troy, N. Y., no date. (From the Institute.)

Rumsey and Company, Catalogue of Hand and Power Pumps, 1915. Seneca Falls, N. Y., no date. (From the Company.)

Sellers, William, & Company, Incorporated, Catalogue of Locomotive Injectors and Boiler Attachments, 1915 Edition. Philadelphia, no date. (From the Company.)

Smithsonian Institution, Annual Report, 1914. Washington, 1915. (From the Institution.)

Société des Arts de Genève, Comptes Rendus de l'Exercice, 1914. Geneva, no date. (From the Society.)

Stecher, Charles Company, Catalogue of Automatic Can Making Machinery. Chicago, no date. (From the Company.)

St. Louis University, Catalogue, 1915. St. Louis, no date. (From the University.)

Syracuse University, Bulletin, 1915. Syracuse, N. Y., no date. (From the University.)

Tasmania Department of Mines, Geological Survey Bulletin No. 19. Hobart, 1915. (From the Department.)

Tufts College, Catalogue, 1914–15. Boston, no date. (From the College.)

Tulane University of Louisiana, Registers, 1912–13, 1913–14, 1914–15. New Orleans, La., no date. (From the University.)

Union College, Catalogue, 1914–15. Schenectady, N. Y., no date. (From the College.)

U. S. Department of Education, Report of the Commissioner, parts 1 and 2, 1914. Washington, 1915. (From the Department.)

U. S. Department of State, Diplomatic and Consular Service of the United States, 1915. No place, no date. (From the U. S. Secretary of State.)

U. S. Department of Terrestrial Magnetism, vol. ii, Land Magnetic Observations, 1911–13, and Reports on Special Researches. Washington, 1915. (From the Department.)

University of Arizona, Catalogue, 1914–15. Tucson, 1915. (From the University.)

University of Florida, Catalogues, 1912–13, 1913–14, 1914–15. Gainesville, no date. (From the University.)

University of Iowa, Catalogue, 1914–15. Iowa City, no date. (From the University.)

University of Maine, Catalogues, 1913–14, 1914–15. Orono, 1913–14. (From the University.)

University of Nevada, Catalogues, 1914–1915. Reno, no date. (From the University.)

University of Oklahoma, Catalogue, 1914–15. Norman, 1915. (From the University.)

University of Texas, Catalogue, 1914–15. Austin, no date. (From the University.)

University of Vermont, Catalogue, 1914–15. Burlington, no date. (From the University.)

University of Virginia, Catalogues, 1913–14, 1914–1915. Charlottesville, no date. (From the University.)

University of Wyoming, Catalogues, 1914, 1915. Laramie, no date. (From the University.)

Upper Iowa University, Catalogue, 1914–15. Fayette, no date. (From the Norton Company.)

Verein Deutscher Chemiker, Mitglieder-Verzeichnis für 1915. Leipzig, no date. (From the Verein.)

Waltham City Documents, 1914. Waltham, Mass., 1915. (From Mr. Richard Steele.)

Washburn-Crosby Company, Wheat and Flour Primer. Minneapolis, Minn., no date. (From the Company.)

Wellesley College, Calendar, 1914–15. Wellesley, Mass., 1915. (From the College.)

West Virginia University, Catalogues, 1912–13, 1913–14, 1914–15. Morgantown, no date. (From the University.)

Wisconsin Historical Society, Proceedings, 1914. Madison, 1915. (From the Society.)

BOOK NOTICES.

CHEMISTRY OF FAMILIAR THINGS, by Samuel Schmucker Sadtler, S.B. Philadelphia, J. B. Lippincott Company, 1915. 320 pages, illustrations, 12mo. Price, $1.75.

Chemistry is intractable material to the popularizer, and his success with it has been small, compared with that achieved by those who have attempted to make astronomy, for instance, intelligible to the layman. The most conspicuous exception is Lassar-Cohn's "Die Chemie im täglichen Leben," which, for reasons not altogether clear to the reviewer, has gone through seven editions and has been translated into thirteen languages.

Professor Sadtler is to be congratulated on the manner in which he has carried out his difficult task. There are few errors. The style is usually dignified and straightforward, and there is a refreshing absence of that tedious semi-jocular vein which the magazine "scientist" appears to consider an inevitable part of his output.

Such criticisms as the reviewer has to offer are largely matters of taste and opinion. The treatment of the period law (pages 28, 29, and 30) would convey nothing to the layman. It is somewhat unfortunate that the Brin oxygen process (page 109) is described as still in use. Lime is hardly a part of the burden of the ordinary iron blast-furnace (page 116). Drying the blast (page 116) is still the exception, though it may become the rule. It is carbon

monoxide, not carbon, which reduces the iron oxide (page 116). The statement (page 116) that the object of the Bessemer process, as worked in the United States, is "to oxidize the silicon and carbon so that they can be removed by lime" will not meet with the approval of the metallurgist. Few chemists will be willing to attach so much importance to Ramsay's results on the "degradation" of copper, thorium, etc. These, however, are minor points. Professor Sadtler is always interesting and usually accurate, and his book deserves to be widely read.

ROBERT H. BRADBURY.

CHEMICAL GERMAN, by Francis C. Phillips. Second edition. Easton, The Chemical Publishing Company, 1915. 252 pages, 8vo. Price, $2.

The first edition of this excellent book was reviewed at some length in this JOURNAL.* The fact that a second edition has appeared so soon after the first is an indication that the book has filled a gap which, in fact, has been noticed by teachers for many years. There seem to be few changes, and sweeping changes were unnecessary, for, being specifically a reader for Chemical German, the book does not grow antiquated with the same speed as an ordinary text. The student who works through Professor Phillips's book faithfully may attack the German chemical literature with confidence. He will find no insuperable difficulties.

ROBERT H. BRADBURY.

BRIEF COURSE IN METALLURGICAL ANALYSIS, by Henry Ziegel. Easton, The Chemical Publishing Company, 1915. 72 pages, quarto. Price, $1.

This is a text-book "written for the use of upper classmen, trained in elementary qualitative and quantitative analysis." The chief characteristic is brevity: there are sixty-six pages; thirty-three are blank, apparently intended for recording students' analyses. There is no index, but the table of contents suffices.

Ordinary methods of analyses of iron ores, iron and steel; limestones; slags and clays; non-ferrous alloys, ores, and mattes are given with extreme brevity, often at the expense of completeness. For example: Under the head of "Silicon in Iron and Steel" four brief paragraphs cover the entire subject, and it is merely stated that "Ferro-silicons require fusion with Na_2CO_3 and Na_2O_2, preferably in a nickel crucible."

Five paragraphs are devoted to determination of Carbon and three to Titanium, and the analyses of other elements are correspondingly briefly disposed of.

The book may be useful as a "tickler" for upper classmen, but will not supplant more complete text-books.

A. E. OUTERBRIDGE, JR.

* December, 1913, issue.

A COMPEND OF MEDICAL CHEMISTRY, INORGANIC AND ORGANIC, INCLUDING URINARY ANALYSIS, by Henry Leffmann, A.M., M.D., Professor of Chemistry in the Woman's Medical College of Pennsylvania and in the Wagner Free Institute of Science. Blakiston's Quiz Compends, sixth edition, revised. 241 pages, 12mo. Philadelphia, P. Blakiston's Son & Co.

The sixth edition of the work has been thoroughly revised and contains the latest information on medical and clinical chemistry, arranged to meet the needs of students in the medical and dental colleges. Since the appearance of the first edition the number of pages has been doubled—an indication of the expansion of chemistry and the popularity of the book among students of medicine.

PUBLICATIONS RECEIVED.

Text-books on Chemical Research and Engineering, Surface Tension and Surface Energy and their Influence on Chemical Phenomena, by R. S. Willows, M.A., D.Sc., and E. Hatschek. Reprinted from *The Chemical World*. 80 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1915. Price, $1.

U. S. Bureau of Mines, Miners' Circular 18, Notes on Miners' Carbide Lamps, by James W. Paul. 10 pages, 8vo. Washington, Government Printing Office, 1915.

On an Investigation of the Accuracy of the Lens and Drop Method of Measuring Refractive Index. R. NETTLETON. (*The Physical Society of London, Proceedings*, vol. xxvii, part v, August 15, 1915.)—If a few drops of liquid be introduced between a plain mirror and a thin convex lens we have in effect a combination of the latter with a plano-concave lens of the liquid. From a knowledge of the curvature of the lower face of the convex lens, together with its focal length and that of the combination, the refractive index of the liquid used can be calculated.

The lens and drop method of comparing refractive indices is a very accurate one when due regard is paid to the choice of lenses and allowance made for the thickness. It is easily adapted to the optical bench and monochromatic light, and measurements may be made very quickly. The method is perhaps seen at its best when employing a suitable converging meniscus to measure refractive indices between 1.3 and 1.4. The method of measuring short radii of curvature in terms of the well-known refractive index of water is also frequently very useful and accurate just when other means are difficult or inaccurate. The lens and drop method may also be of service in finding the refractive index of the material of the lens. The apparatus employed is very suitable as providing a laboratory experiment for advanced students in view of the accuracy of the results obtained by the inexpensive adaptation of standard apparatus.

CURRENT TOPICS

Uses of Chromic Iron Ores. (*United States Geological Survey Press Bulletin No. 233,* September, 1915.)—Chromic iron ores are used for diverse purposes. They are in great demand in making refractory chrome bricks and furnace lining; in making alloys; in manufacturing steel for cutting tools, projectiles, and armor plate; in a great chemical industry which produces many colors and dyes, and in tanning. California produced almost the entire annual output of chromic iron ore reported in the United States in 1914, and a small output of chromite sand was reported from several points near Baltimore, Md., in that year. The opening of the Panama Canal is expected to obviate in large measure the difficulty formerly experienced in supplying California chromite to eastern manufacturers.

A Process for the Rapid Estimation of the Quantity of Metal Deposited in Nickel Plating. M. PONTIO. (*Comptes Rendus,* vol. 161, No. 7, August 17, 1915.)—This method in principle depends upon the combined action of hydrogen peroxide and mineral acids in contact with iron and copper. If a plate of metal or other object nickelled by electrolysis be introduced in a cold dilute solution of HCl and 12-volume H_2O_2 of suitable proportions: (1) A more or less rapid penetration of the oxidizing mixture through the interstices of the electrolytic deposit of nickel. The speed of this penetration is a function of the quantity of metal deposited and the proximity of its molecules; and, in the case of a sufficient and uniformly distributed thickness, becomes effective only when the solution has destroyed a part of the nickel to reach the copper underneath. (2) A slow attack in the cold of the nickel which will aid the penetration of the oxidizing mixture to the metal underneath. Three cases may occur in which this action will take place:

(*a*) *When the underlying metal is copper:* If the coating of nickel is thin (less than 1 mg. per sq. cm.), the formation of $CuCl_2 2H_2O$ will take place at once. If the coating of nickel is sufficient (from 2 mg. to 3 mg. per sq. cm.), the formation of $CuCl_2 2H_2O$ will be accompanied with $NiCl_2 6H_2O$, and in this case the formation of these salts, determined by the green color, will be the more rapid as the nickel coating is the thinner, the nickel being only slightly acted upon by the reagent.

(*b*) *When the underlying metal is iron:* In this case the formation of perchloride of iron is much more rapid than that of the cupric chloride for an equal quantity of nickel.

(*c*) *When the underlying metal is iron, but is coated with copper before being nickelled:* If the layer of nickel is thin, the copper will appear immediately, followed closely by the appearance of the iron. If the nickel coating is heavy, only the iron will appear at the beginning of the reaction, followed by the appearance of copper after a time, which will be proportional to the quantity of nickel deposited.

In these three cases, then, the appearance of salts of iron and copper determines the end of the reaction, observable by the final formation of the double salt (for copper and nickel), and aided by a cautious addition to the mixture of a requisite quantity of concentrated ammonia.

Battery Zincs: Some Causes of Defective Service. R. JOB and F. F. WHITE. (*American Society for Testing Materials, Proceedings,* June 22–26, 1915.)—The serviceability of the zinc element of a gravity cell, such as is commonly used in railway service, is generally considered to depend mainly upon its composition, and it is specified usually that the percentage of iron shall be a minimum of about 0.10 per cent., lead not to exceed 0.50 per cent., and not less than 2 per cent. of mercury.

Of two lots having the requisite chemical composition, one proved altogether unsatisfactory in service. The cause was disclosed by etching and microscopic examination. The satisfactory sample proved to be of fine grain and of uniform structure clear to the outside surface, while the defective sample was of coarse grain, indicating pouring into moulds of a high temperature. The natural inference that the outside metal contained little mercury was verified by the analysis of borings near the surface, the satisfactory sample showing 2.49 per cent. and the defective sample 0.64 per cent.

It is a well-known fact that mercury volatilizes to a considerable extent when added to molten zinc, unless suitable precautions are taken; consequently it is necessary to avoid not only overheating the bath of metal, but also to keep the moulds cooled. Evidently in the case of the defective zincs this latter practice had not been followed, hence the proportion of mercury upon the surface of the zincs was extremely low and insufficient to protect the zincs from local action.

Effect of Transient Voltages in Dielectrics. F. W. PEEK, JR. (*Proceedings of the American Institute of Electrical Engineers,* vol. xxxiv, No. 8, August, 1915.)—In practice, failures of dielectrics are generally caused by transient voltages. It is therefore of great practical importance to determine the various phenomena affecting the strength of dielectrics and means of protecting them when they are subjected to known transient voltages. An impulse generator from which impulse voltages of any given wave-front, length of tail, etc., can be obtained, is described.

Energy is required to rupture gaseous, liquid, and solid dielectrics: this introduces a time element. Thus, on account of this

time lag, when voltage is applied at a very rapid rate, as by impulse, spark-over does not occur when the continuously-applied breakdown voltage is reached. The voltage "overshoots" or rises above this value during the time rupture is taking place. This excess or rise in voltage above the continuously-applied breakdown value is greater the greater the rate of application. The time depends upon the nature of the dielectric, the dielectric field, the shape and spacing of the electrodes, initial ionization, etc.

The strength of air between spheres and needles for impulses of different front, length of tail, etc., is given, as well as the time in micro-seconds and the voltage required to rupture air between spheres and needles, on the front of waves rising at various rates.

Transient spark-over and corona voltages for wires, surface spark-over, effects of solarity, air density, practical application, etc., are given.

Transient spark-over voltage and time are recorded for oil and various solid dielectrics.

The general laws of breakdown of dielectrics by transient voltages are summarized.

Natural Gas Production in 1914. J. D. NORTHROP. (*United States Geological Survey Press Bulletin*, No. 236, September, 1915.)—Statistics compiled under the supervision of J. D. Northrop, of the United States Geological Survey, show that the quantity of natural gas commercially utilized in the United States in 1914 exceeded that so utilized in any previous year in the history of the natural gas industry. The quantity produced, which amounted to approximately 591,866,733,000 cubic feet, valued at $94,115,524, constitutes a new record of production, exceeding by nearly 10,000,000,000 cubic feet, or almost 2 per cent., the former record, established in 1913.

Increases in output in 1914 over 1913 were credited to New York, Ohio, Oklahoma, Texas, Louisiana, Alabama, Iowa, and California, the State last named alone recording a gain of nearly 7,000,000,000 cubic feet. Other gas-producing States recorded declines in output, the greatest of which, that of Pennsylvania, amounting to slightly more than 10,000,000,000 cubic feet.

The increases in gas production may be attributed to various causes—in New York to the increased drilling activity stimulated by the advancing petroleum market in 1913 and the early part of 1914; in Ohio to local extensions of the productive fields of the gas belt in the central part of the State and to the development of an important gas pool in the vicinity of Cleveland, Cuyahoga County; in Oklahoma to the development of gas reserves in the Cushing field, Creek County, and the Healdton field, Carter County, as well as to a decided expansion of the local casinghead gasoline industry; in Texas to a greater utilization of the gas supplies available in the Petrolia and Mexia fields; in Louisiana to the greater development of the gas

reserves in Caddo and De Soto parishes; and in California to increased demands for domestic consumption in Los Angeles and adjacent towns in the southern part of the State, as well as for industrial consumption in the casinghead gasoline industry.

Of the record-breaking production of natural gas credited to 1914 it is estimated that a total of 203,104,358,000 cubic feet, about 34 per cent., was supplied to domestic consumers at an average price of 28.04 cents a thousand cubic feet, and that 388,762,375,000 cubic feet, the remaining 66 per cent., was supplied to industrial consumers at an average price of 9.56 cents a thousand cubic feet. During the last four years the ratio of domestic to industrial consumption has varied but slightly. Formerly, however, a relatively greater proportion of the annual yield was supplied to industrial consumers.

Conduction of Electricity through Metals. J. J. THOMSON. (*The Physical Society of London, Proceedings*, vol. xxvii, part v, August 15, 1915.)—The investigations of Kamerlingh Onnes on the resistance of metals at the temperature of liquid helium have led to results which are of vital importance in the theory of metallic conduction: they have shown, for example, that some metals can exist in a state where their specific resistance is less than one hundred thousand millionth part of that at 0° C. The transition from a state in which the resistance is diminishing normally with the temperature to the one where they possess this super-conductivity takes place abruptly at a definite temperature, and the difference in the electric properties of the metal above and below this temperature is as well marked as the difference in elastic properties when a solid melts or in the magnetic ones when a piece of iron passes through the temperature of recalescence. One of the most remarkable effects discovered by Kamerlingh Onnes is that when a current was started in a small ring of lead at a temperature of about 4° absolute by bringing a magnet close to it, the current, instead of dying away, as it would have done at 0° C., as soon as the magnet was stopped, went on with practically undiminished intensity, its rate of decay being so slow that Kamerlingh Onnes estimated that it would take four days to fall to half its initial value This power of transmitting a current for long periods when no external electromotive force acts on the metal is one that has to be accounted for by any theory of metallic conduction: any such theory must indicate that in certain metals a change in electrical state takes place at a definite temperature; that above this temperature the current dies away almost instantaneously after the electromotive force is removed, while below it the current may persist for days without undergoing any perceptible diminution.

Government Regulation of Water Powers in European Countries. (*United States Geological Survey, Water-Supply Paper 238.*)—One of the most important problems in the political economy

of a nation is the control of water power, and the fact that Congress recognizes its importance is shown by the time devoted to the subject by the United States House of Representatives during the latter part of 1914. It is always interesting and usually helpful, in considering the conditions involved in this problem, to find how other countries have dealt with somewhat similar conditions, so that Water-Supply Paper 238—"The Public Utility of Water Powers and their Governmental Regulation"—issued by the United States Geological Survey in 1910, contains much valuable data. This report, prepared by René Tavernier, chief engineer of the Department of Public Works of France, in conjunction with the United States Geological Survey, treats of the manner in which France, Switzerland, and Italy have dealt with the problem of utilizing more satisfactorily the water powers afforded by the streams in those countries. The French regulations take cognizance of two kinds of streams—first, rivers that are navigable neither for vessels nor rafts, over which the French Minister of Agriculture exercises certain police powers and in which the riparian landowners possess certain rights; and, second, streams that are navigable by vessels or rafts, which lie within the public domain and which are administered by the Minister of Public Works. In Switzerland control of watercourses that are navigable for neither ships nor rafts is retained by the cantons and communes; in Italy the waters are public property, concessions for development being issued by the government.

The laws in force in France, Switzerland, and Italy are given in the report, together with a brief discussion of the results of their operation, as well as their defects and the probability of future changes in the laws.

The Improvement of High Boiling Petroleum Oils and the Manufacture of Gasoline as a By-product Therefrom by the Action of Aluminum Chloride. A. M. McAFEE. (*Journal of Industrial and Engineering Chemistry,* vol. 7, No. 9, September, 1915.) —In nearly all cases, the conversion of high boiling petroleum oils into lower boiling-point oils has been effected by the process known as cracking; that is, heating to a sufficient temperature to cause the high boiling oils to become unstable and break down into lower boiling oils. Among the many difficulties occurring in the operation of this process is the danger to the operators and the plant incident to the high temperatures and pressures required, along with the deposit of hard coke at the hottest part of the heating element.

In a paper read before the American Institute of Chemical Engineers the author describes the results of tests made at the Gulf Refining Company's plant of the breaking down of high boiling-point oils by the use of aluminum chloride.

In the practical operation of this process, crude petroleum of any kind is first distilled until the naturally occurring gasoline and kero-

sene is distilled off. In many of our crude oils there is substantially no gasoline present and very little kerosene. But in any event the crude oil is first heated to free it of any moisture it may contain, as the oil must be perfectly dry before adding the aluminum chloride. Anhydrous aluminum chloride is then added to the remaining residual oil and the mixture brought to boiling. The entire distillation extends over a period of 24 to 48 hours at a temperature generally between 500° F. and 550° F. No extra pressure of vacuum or special apparatus is employed; any still provided with a stirrer suffices. Unlike some of the products of cracking, the low-boiling oils produced are sweet smelling, water white, and saturated.

The recovery of the aluminum chloride is an important step in the process and a pointed feature. While the cost of this chemical is lowered when produced on a large scale, it is necessary to recover this reagent to make the process of commercial value.

Emergency Exit from Boiler-rooms. ANON. (*Scientific American*, vol. cxiii, No. 10, September 4, 1915.)—There is no part of a ship's complement that is exposed to such imminent danger in case of disaster as the engine- and boiler-room forces, and particularly the boiler-room under pressure makes it necessary that all means of access to the boiler-room compartments and exit from them shall be closed while forced draft is in use. In the majority of cases the means of exit from a boiler-room consist of openings on the roof, reached by steel ladders which are normally closed by steel covers.

In order to provide an effectively closed stoke-hole system with a ready means of exit in an emergency, Mr. Ernest H. Peabody, of the Babcock & Wilcox Boiler Company, has designed an ingenious and very effective water-seal arrangement at the exit opening through the bulkhead. In the floor of the boiler-room a tank is built about the opening, which is filled with water approximately to the level of the floor. The bulkhead between the fireroom and the escape front is brought down several inches below the surface of the water in the tank, thereby providing an effective water seal to prevent the passage of steam.

In the event of an accident followed by a rush of steam into the boiler-room, the firemen jump into the water, pass under the lower edge of the bulkhead, and so escape.

Molten Zinc as a Reagent for the Microscopic Etching of Iron and Steel. J. L. JONES. (*American Society for Testing Materials*, Annual Meeting, June 22–26, 1915.)—The samples are immersed in molten zinc for varying periods, low-carbon steels requiring a longer time than high-carbon steels. The adherent dross and metallic zinc are removed partly by mechanical means and partly by the aid of dilute sulphuric acid. Defects in steel are thus plainly disclosed, porous areas being attacked to a marked degree, while the non-porous areas are scarcely attacked at all.

High-carbon steels are more readily attacked than low-carbon steels, and lack of uniformity may be thus ascertained, as well as the depth and character of case-hardening.

High-speed steels are etched in a remarkable manner that indicates that the constituent metals are seldom, if ever, perfectly alloyed. The deeply-etched spots are probably very high-carbon areas that are vigorously attacked by the molten zinc.

Steel-reinforced Aluminum Cables. E. T. DRIVER and E. V. PAUNELL. (*Electrical World*, vol. 66, No. 10, September 4, 1915.)—For many years the adoption of aluminum conductors for long-distance transmission lines has been found economical. However, owing to the lower tensile strength of this material, it is impossible to pull up such conductors as tightly as copper. The greater sag on the aluminum cables necessitates higher and more expensive towers, and in some cases the economy resulting from the use of the light metal has been more than counterbalanced by this fact. This has been the main reason for the introduction of the steel-centre aluminum conductors and the fact that such composite cables have been in use for more than ten years indicates that this project is now beyond the experimental stage.

Among a number of important power undertakings using this type of conductor, two alone employ in the aggregate 70,000,000 pounds of steel-aluminum conductors.

The simplest form is that in which six aluminum strands are laid up around a central steel wire, all of the seven strands being of the same size. This is used for the smallest sizes of cable up to about No. 1, A.W.G. (B. & S.). Larger areas, up to about 225,000 circ. mils, usually have the single steel wire replaced by a seven-wire steel cable of the same area. The ratio of steel to aluminum is the same in both cases. Cables larger than 225,000 circ. mils are usually of thirty-seven or sixty-one strands.

At present, under the average market conditions, a transmission system employing aluminum conductors is frequently cheaper than the equivalent line erected with copper, notwithstanding the higher cost of the towers in the former case. If the towers can be reduced in cost, the economic advantages are more than ever on the side of aluminum, particularly as the extra cost involved by the steel core is trifling. Formulas and data are given for the computation of sag and stress for these composite conductors.

Visibility. C. C. PATERSON. (*Illuminating Engineering*, vol. viii, No. 5, May, 1915.)—The discrimination of detail in certain circumstances depends almost entirely either on shadow or on the direction of the incident light. The question has a wide practical application in the manipulation of unicolored fabrics with no natural contrasts. A person doing needlework with such materials depends for the discrimination of the detailed strands of the fabric on the small shadows

cast by one strand on the next, and on the varying brightness over the curved surfaces of each individual strand. Both these factors depend on the unidirectional character of the light incident on the material and the inefficiency of thoroughly-diffused (that is, indirect) light, for such work is most marked. The writer has for ten years used indirect lighting for domestic use, and for a long time ridiculed the assertion that was often made that it was a most unsatisfactory light by which to do needlework, particularly darning. After experiment, however, it is clear that the contention is sound, and that there is nothing so good as unidirectional light giving harsh shadows for the discrimination of detail in needlework of all kinds. Indirect lighting, with its soft shadows, is an ideal light for domestic use except in respect to this one particular.

Sandstone Varieties. (*U. S. Geological Survey.*)—The products of rock decomposition may be reconsolidated either by great pressure or by the injection of cementing materials, or by both. Thus sands are formed into sandstones, clays become shales, and calcareous deposits yield limestone. Aside from their cementing materials, sandstones differ in composition exactly as did the sands of which they are composed. Sandstone may be nearly pure quartz, or quartz and feldspar, or quartz, feldspar, and mica, and it may vary in texture from the fine to the coarse. Some sandstone is so coarse that it will hold six quarts of water to the cubic foot, and underground deposits of such sandstone form excellent reservoirs, which may yield a never-failing supply of water. An arkose sandstone from the quicksilver region of California, made up of granitic detritus, was found to contain quartz, orthoclase, oligoclase, biotite, muscovite, hornblende, titanite, rutile, tourmaline, and apatite. In short, all the rock-forming minerals which can in any way survive the destruction or grinding up of a rock may be found in sands, and therefore in sandstones.

An Instrument for the Optical Delineation and Projection of Physical Curves. J. A. FLEMING. (*The Physical Society of London, Proceedings,* vol. xxvii, part iv, June 15, 1915.)—This instrument is designed for projecting on to a screen or photographing on a plate such curves as magnetic hysteresis, resonance or characteristic curves which can be performed slowly or are non-periodic or non-repetitive. It consists of a base-board on which is fixed a thin wooden ring wound over with one layer, in close turns, of insulated Eureka wire. The insulation on the top surface is removed so as to expose the wire. At the centre of the ring there is a pivot which carries a radial arm, the end of which rubs on the base Eureka wire. The ends of the Eureka wire are connected to a battery, and the middle point of the wire is connected to a terminal and also the centre of the radial arm to another terminal. The arrangement forms a circular potentiometer, so that any required fraction of the bat-

tery voltage can be produced in either direction between the last-mentioned two terminals. On the same base there is a rectangular mirror slung on a longitudinal axis, which mirror is tilted by a thread wound round the shaft of the radial arm of the potentiometer. Hence if a ray of light from a mirror magnetometer or galvanometer is reflected to a tilting mirror, and thence to another fixed mirror with its axis at right angles to that of the other, and thence to the screen, the spot of light will have two motions,—one a horizontal one proportional to the displacement of the radial arm and therefore to the potentiometer displacement of the two terminals, and another vertical motion proportional to the deflection of the galvanometer or magnetometer. If, then, we place behind the magnetometer a long coil having a long iron wire within it and send a current through this coil which is supplied from the potentiometer travelling terminals, the spot of light will be actuated by two motions,—one a horizontal one proportional to the magnetizing force, and the other a vertical one proportional to the central flux density in the iron. It will therefore describe a hysteresis curve when the radial arm is moved to and fro cyclically through a certain arc or angle. In the same manner the instrument can be used to delineate characteristic curves of wireless detectors or rectifiers or other devices. By using a rotating condenser of variable capacity in place of the circular potentiometer, the instrument can be used for delineating resonance curves of wireless telegraph plants.

Muddiest of Rivers. (*U. S. Geological Survey,* Bulletin 612.)—The Missouri is the muddiest river in the Mississippi Valley; it carries more silt than any other large river in the United States except possibly the Rio Grande and the Colorado. For every square mile of country drained it carries downstream 381 tons of dissolved and suspended matter each year. In other words, the river gathers annually from the country that it drains more than 123,000,000 tons of silt and soluble matter, some of which it distributes over the flood plains below to form productive agricultural lands, but most of which finds its way at last to the Gulf of Mexico.

It is by means of data of this kind that geologists compute the rate at which the lands are being eroded away. It has been shown that the Missouri River is lowering the surface of the land drained by it at the rate of one foot in 6036 years. The surface of the United States as a whole is now being worn down at the rate of one foot in 9120 years. It has been estimated that if this erosive action of the streams of the United States could have been concentrated on the Isthmus of Panama it would have dug in 73 days the canal which has just been completed, after ten years' work, with the most powerful appliances yet devised by man.

A Curious Mineral. (*United States Geological Survey, Press Bulletin No. 235,* September, 1915.)—Perhaps the most curious mineral found in the United States is staurolite, otherwise known

as the "fairy stone." This is an iron-aluminum silicate found only in Virginia and North Carolina, the reddish-brown and brownish-black crystals occurring in well-defined single and double crosses. There is some commercial demand for the crosses as curios, which are worn as watch charms or on chains in the manner of a locket or lavaliere—a demand perhaps stimulated by a legend relating to their fairy origin.

The Extraction and Separation of the Radioactive Constituents of Carnotite. H. M. PLUM. (*The Journal of the American Chemical Society,* vol. xxxvii, No. 8, August, 1915.)—Ever since the discovery of radium by Mme. Curie, and the announcement of its wonderful properties, there has been a very great demand for this element. On account of its scientific interest, such extensive investigations have been carried out that the supply of radium has at all times fallen short of the demand. The more recent claim that it has therapeutic value in the treatment of such diseases as cancer has so greatly increased the demand that the study of the radium-producing ores, along with the best methods of extracting the radioactive material, has become extremely important.

In this paper a careful study has been made of a Colorado carnotite and a satisfactory method worked out for the extraction of the radioactive ingredients. Several of the commercial methods now in use for removing vanadium and uranium from a carnotite ore have been examined and modified so as to be effective in treating our ore, which was found not to be a pure carnotite, but a mixture of this mineral with a vanadiferous silicate containing vanadium in a condition difficult to remove. The method finally adopted gives good results. The uranium is removed by boiling the carnotite concentrates with a sodium carbonate solution precipitated as a uranyl sodium carbonate by merely concentrating the filtrate, and the soda is again recovered. The radium, actinium, and radio-lead are contained in the filtrate obtained by boiling the residue insoluble in soda solution with hydrochloric acid. That part of the radium still held in the residue is then removed with boiling nitric acid. The ionium is finally recovered from residue by boiling with sulphuric acid, and is then concentrated with cerium rather than with thorium, from which it cannot be separated by any known reaction.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA